



US008697498B2

(12) **United States Patent**  
**Jang et al.**

(10) **Patent No.:** **US 8,697,498 B2**  
(45) **Date of Patent:** **Apr. 15, 2014**

(54) **METHODS OF MANUFACTURING THREE DIMENSIONAL SEMICONDUCTOR MEMORY DEVICES USING SUB-PLATES**

(75) Inventors: **Byong-hyun Jang**, Suwon-si (KR);  
**Dongchul Yoo**, Seongnam-si (KR);  
**Chanjin Park**, Yongin-si (KR); **Hanmei Choi**, Seoul (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.** (KR)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 81 days.

(21) Appl. No.: **13/284,435**

(22) Filed: **Oct. 28, 2011**

(65) **Prior Publication Data**

US 2012/0135583 A1 May 31, 2012

(30) **Foreign Application Priority Data**

Nov. 29, 2010 (KR) ..... 10-2010-0119904

(51) **Int. Cl.**  
**H01L 21/82** (2006.01)  
**H01L 21/00** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **438/128**; 438/154; 438/217; 438/257;  
438/588; 438/591; 257/E29.052

(58) **Field of Classification Search**  
USPC ..... 438/128, 154, 217, 257, 588, 591;  
257/E29.052

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

|                   |         |                   |         |
|-------------------|---------|-------------------|---------|
| 7,679,133 B2      | 3/2010  | Son et al.        |         |
| 2006/0076602 A1 * | 4/2006  | Harter et al.     | 257/301 |
| 2007/0158736 A1 * | 7/2007  | Arai et al.       | 257/315 |
| 2007/0252201 A1 * | 11/2007 | Kito et al.       | 257/331 |
| 2008/0265235 A1   | 10/2008 | Kamigaichi et al. |         |
| 2009/0242966 A1   | 10/2009 | Son et al.        |         |

FOREIGN PATENT DOCUMENTS

|    |                 |         |
|----|-----------------|---------|
| JP | 2008-277543     | 11/2008 |
| JP | 2009-117843     | 5/2009  |
| KR | 1020080096432 A | 10/2008 |
| KR | 1020090047614 A | 5/2009  |
| KR | 1020090093770 A | 9/2009  |

\* cited by examiner

*Primary Examiner* — Thanh V Pham

(74) *Attorney, Agent, or Firm* — Myers Bigel Sibley & Sajovec, P.A.

(57) **ABSTRACT**

A method of manufacturing a Three Dimensional (3D) semiconductor memory device can be provided by forming at least one trench in a plate stack structure to divide the plate stack structure into a plurality of sub-plate stack structures between forming a plurality of vertical active patterns in the plate stack structure and forming pads of a stepped structure from the plate stack structure.

**10 Claims, 39 Drawing Sheets**

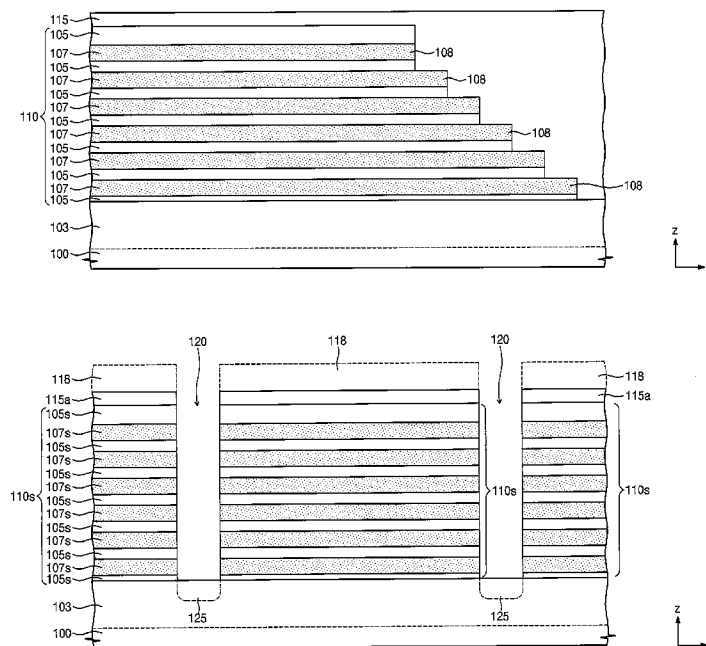


Fig. 1A

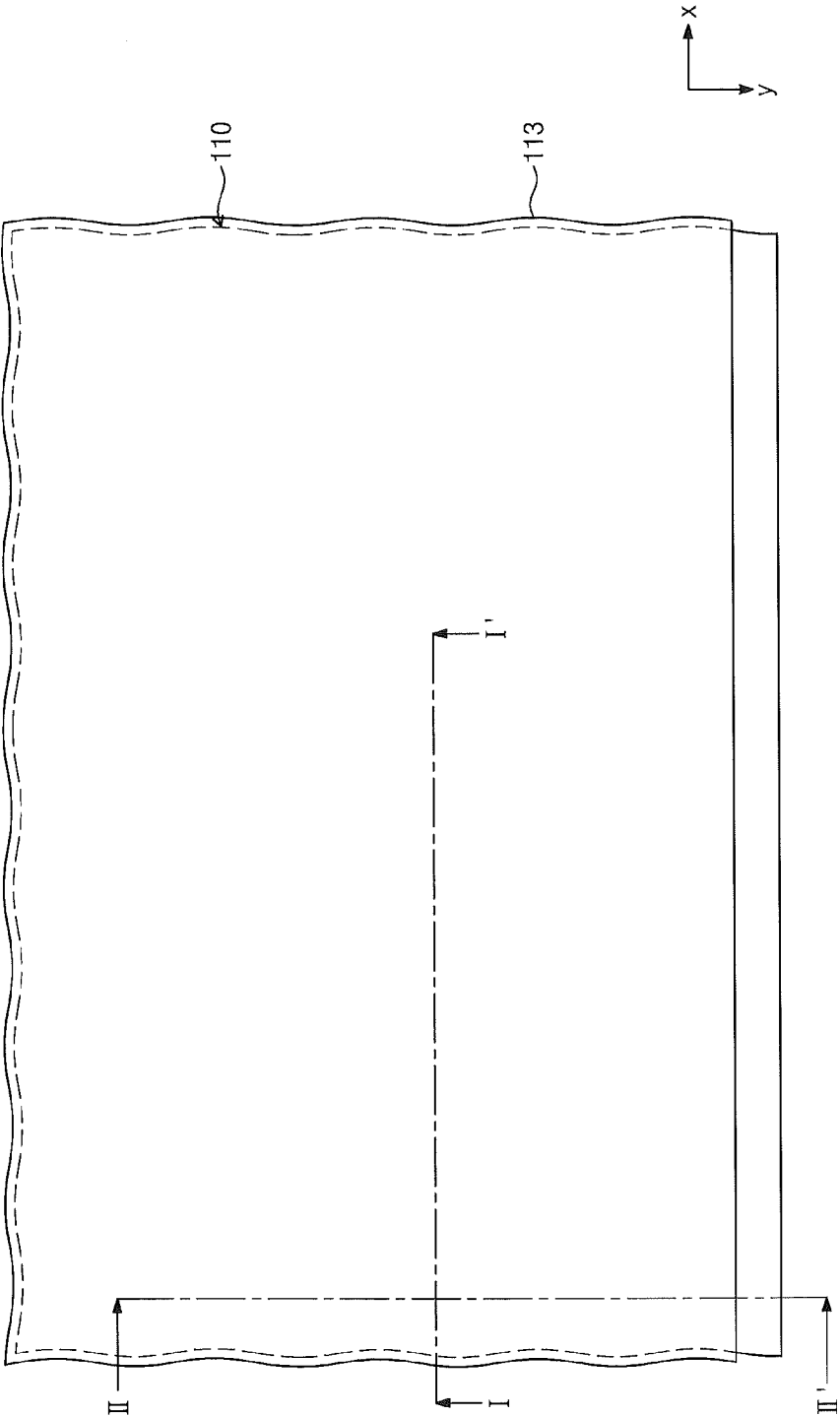


Fig. 1B

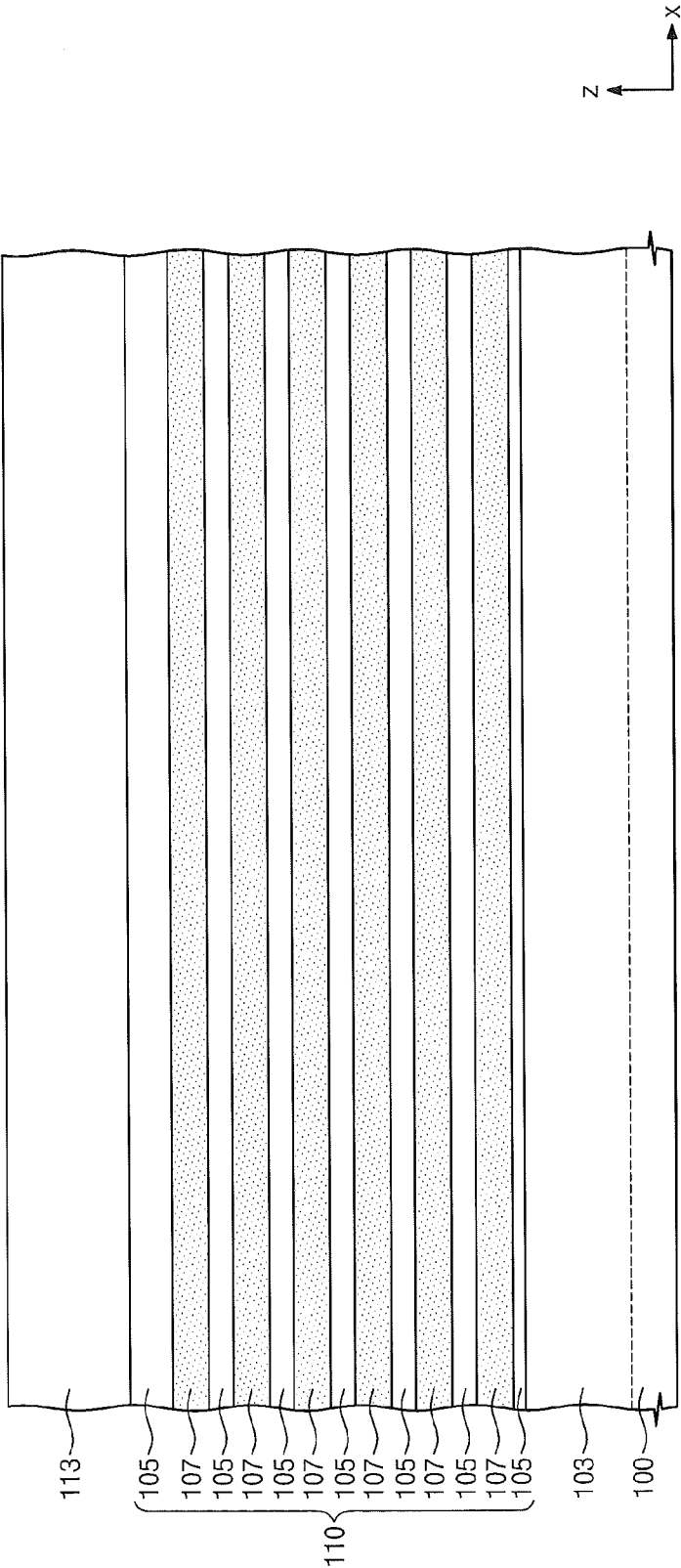




Fig. 2A

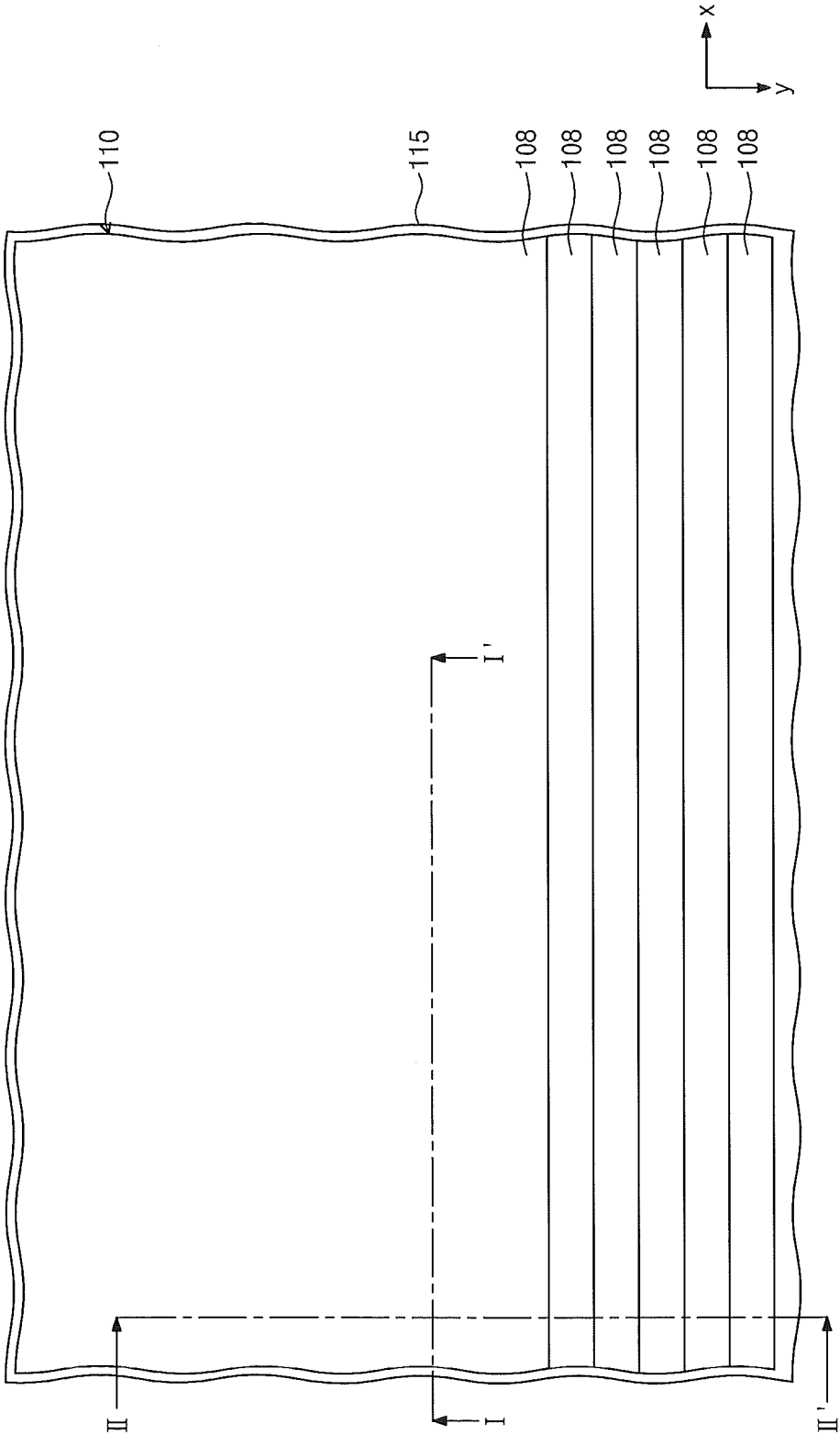


Fig. 2B

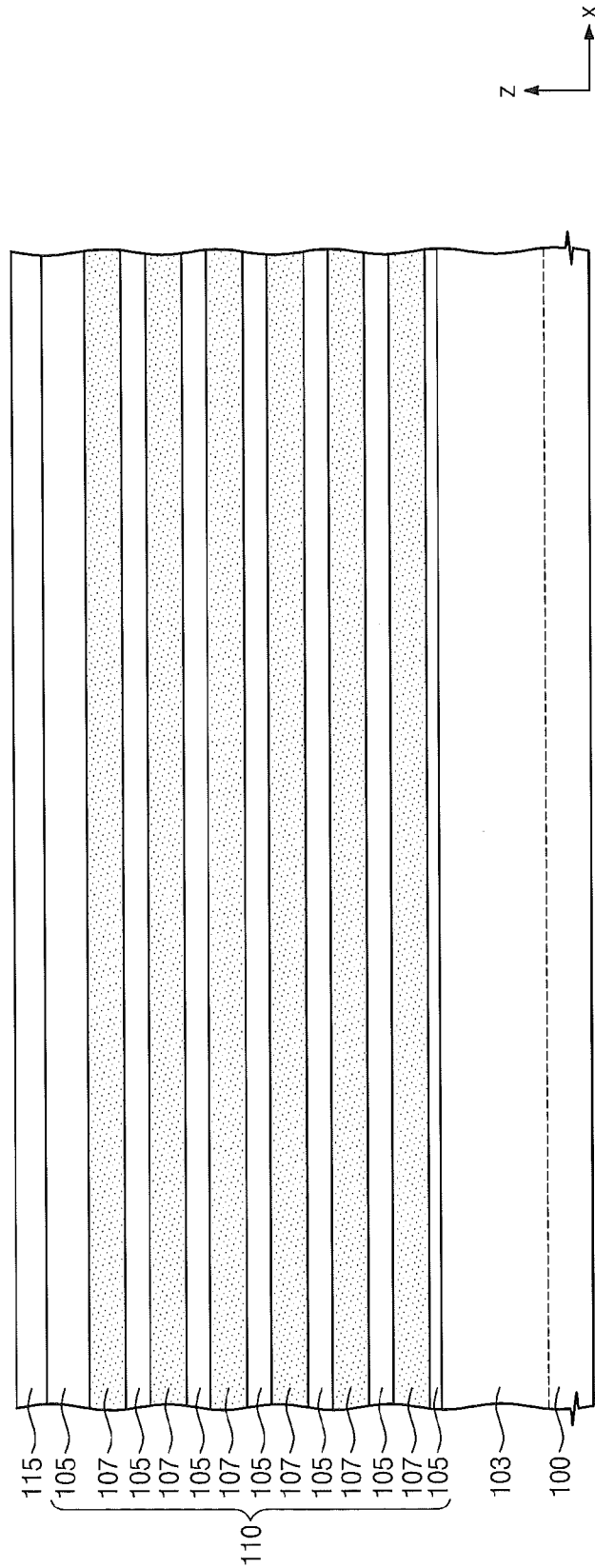


Fig. 2C

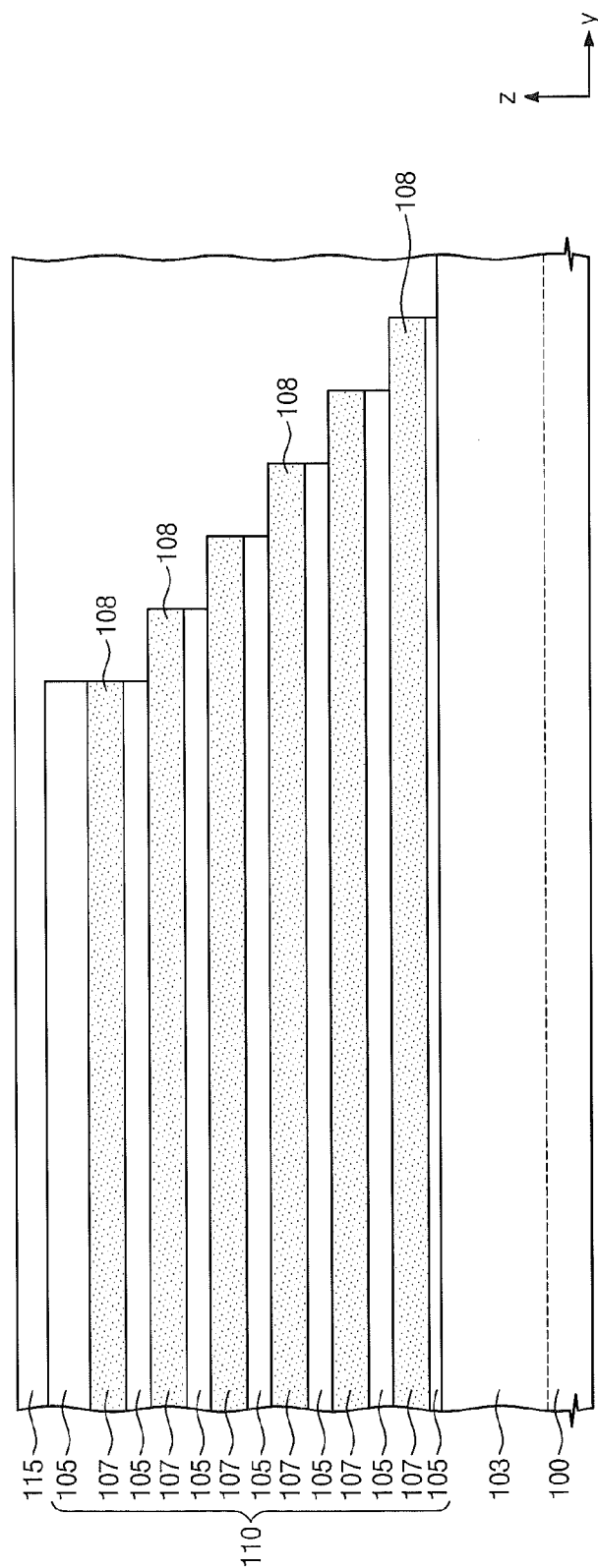


Fig. 3A

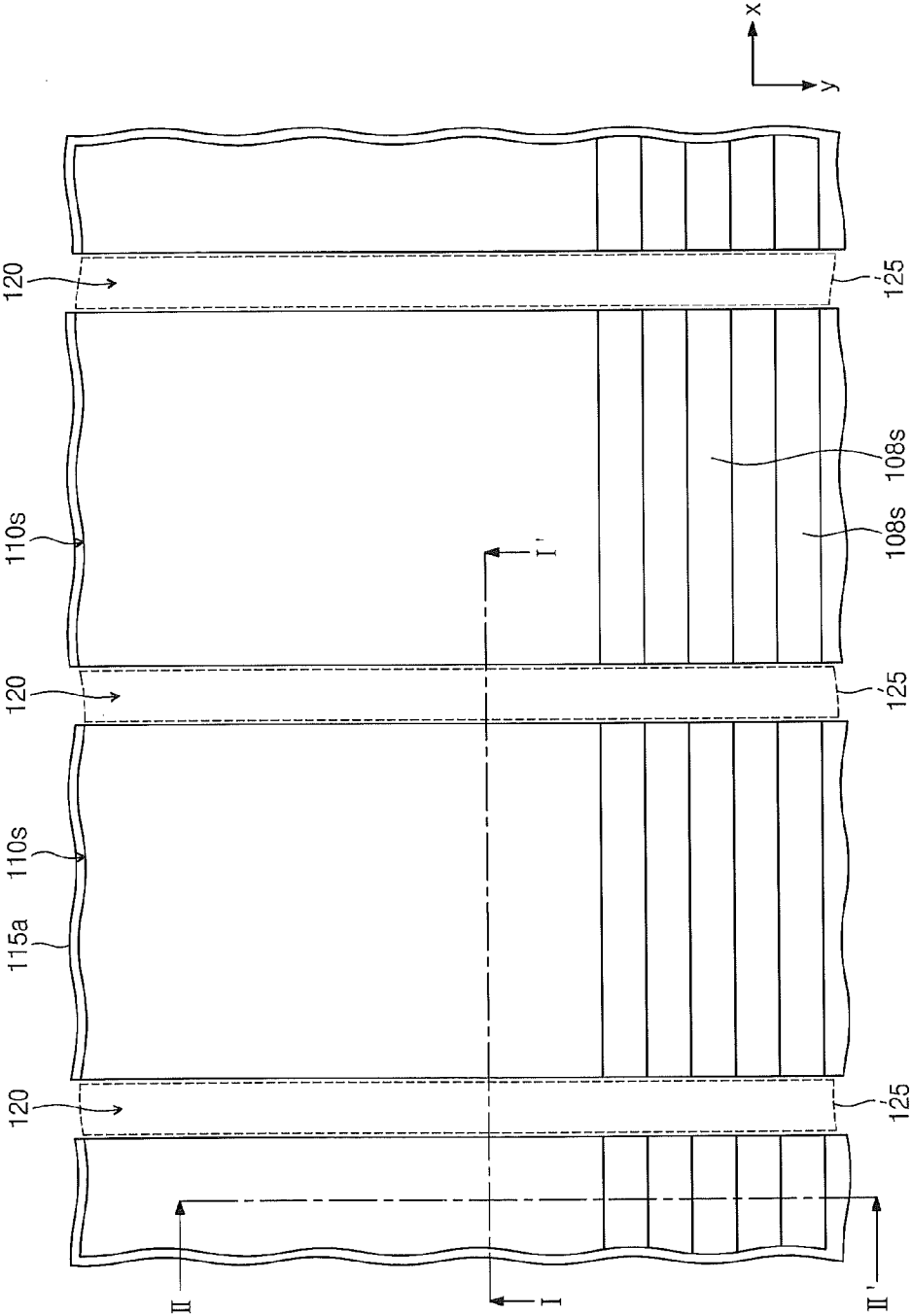


Fig. 3B

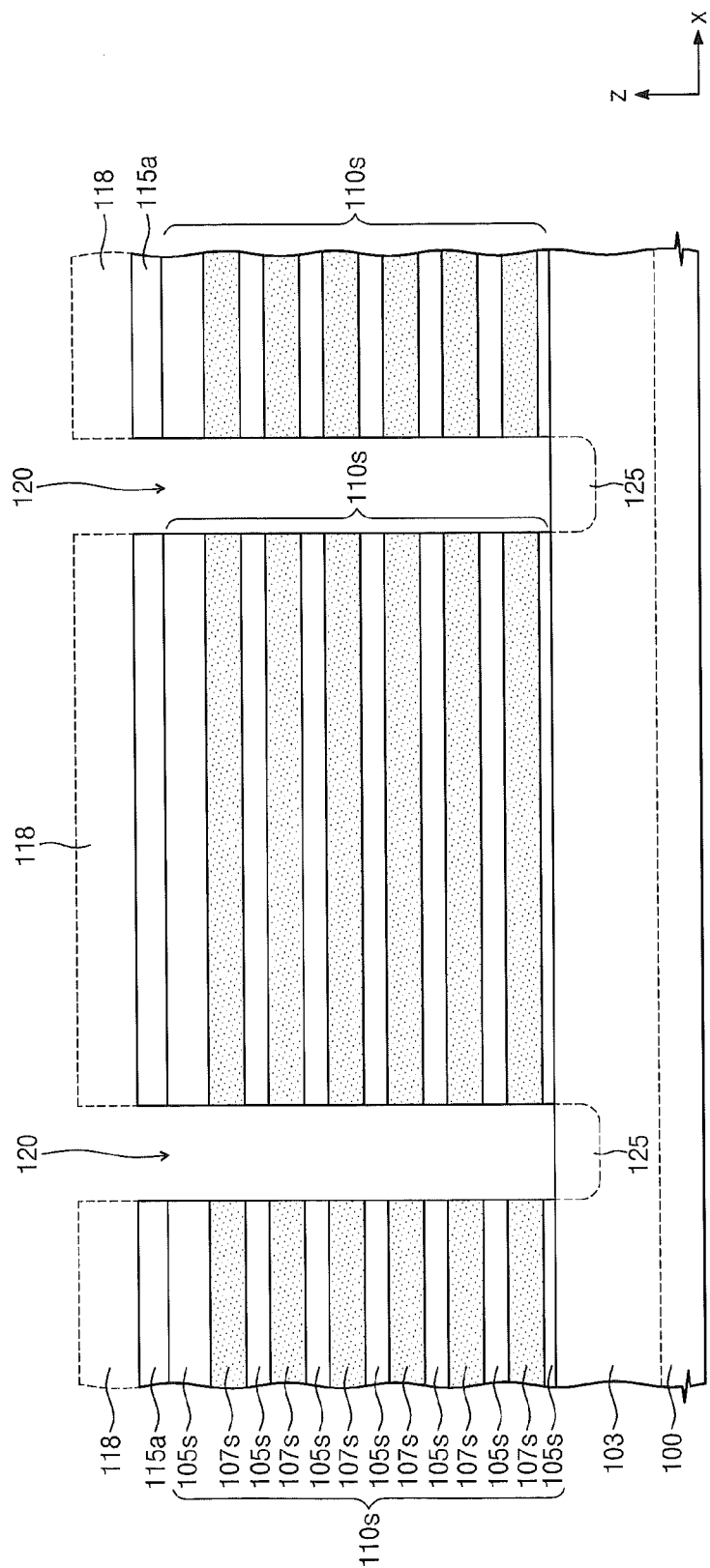


Fig. 3C

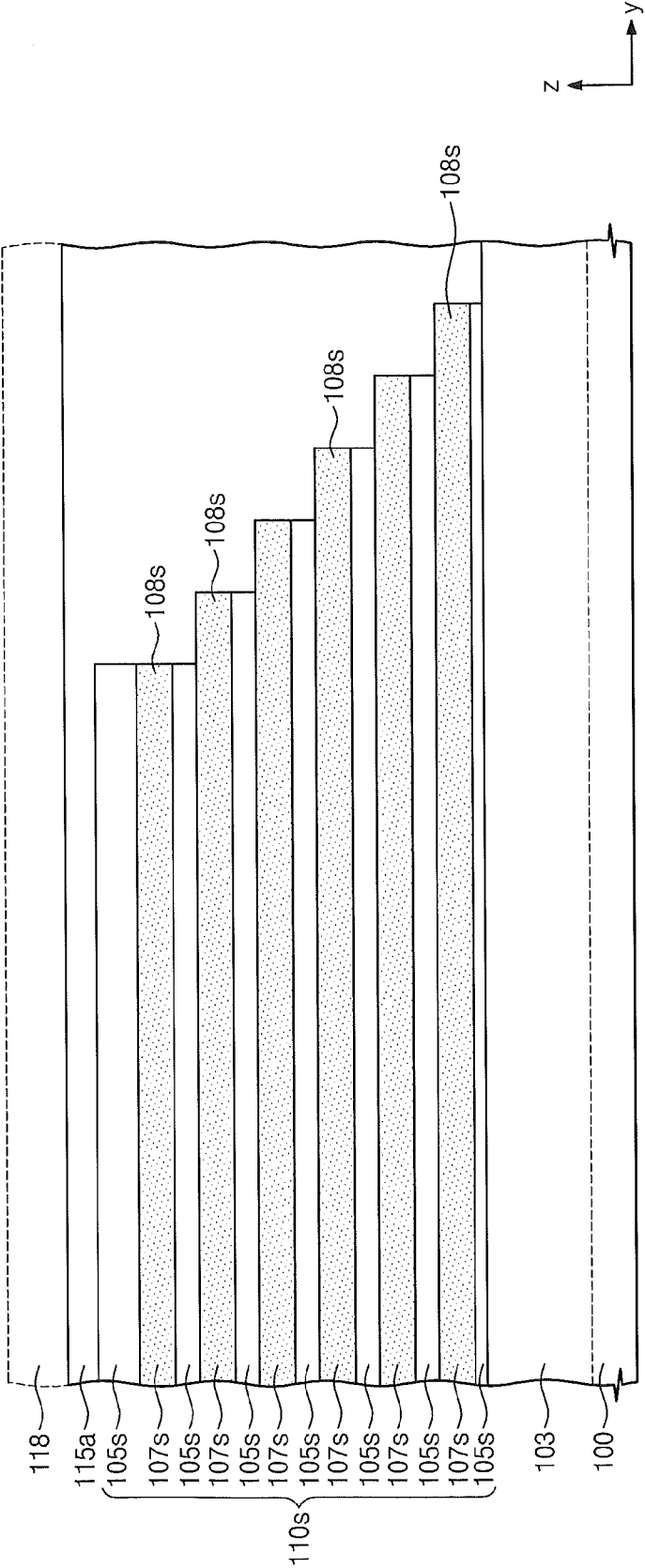


Fig. 4A

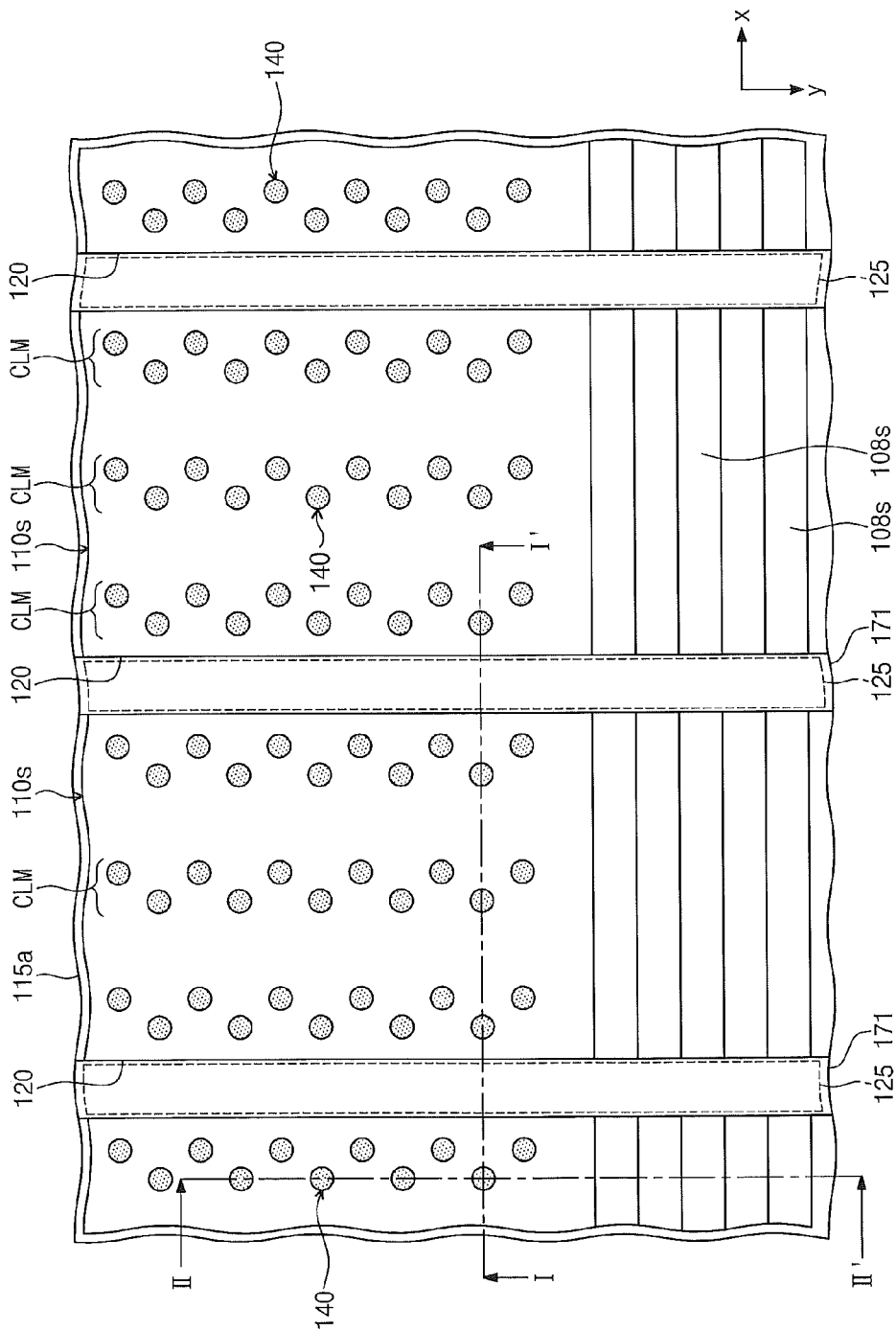


Fig. 4B

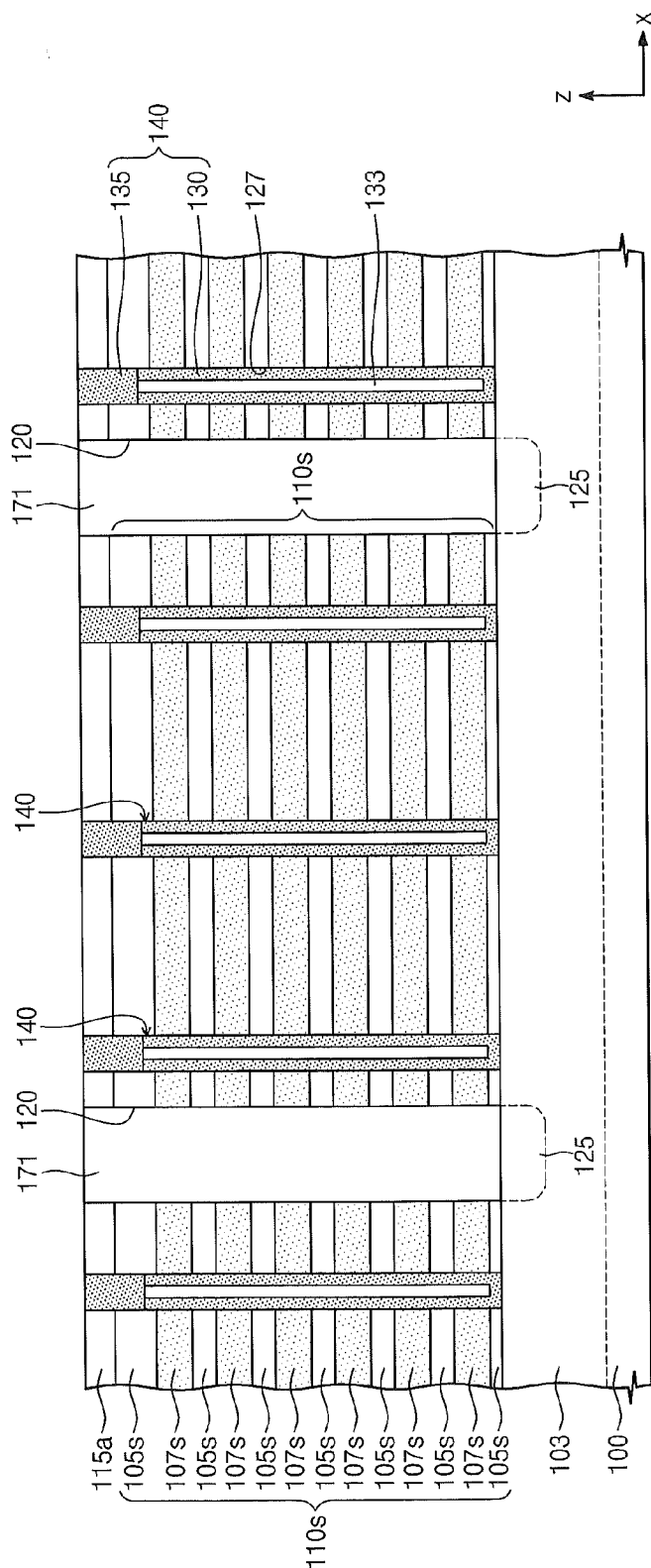


Fig. 4C

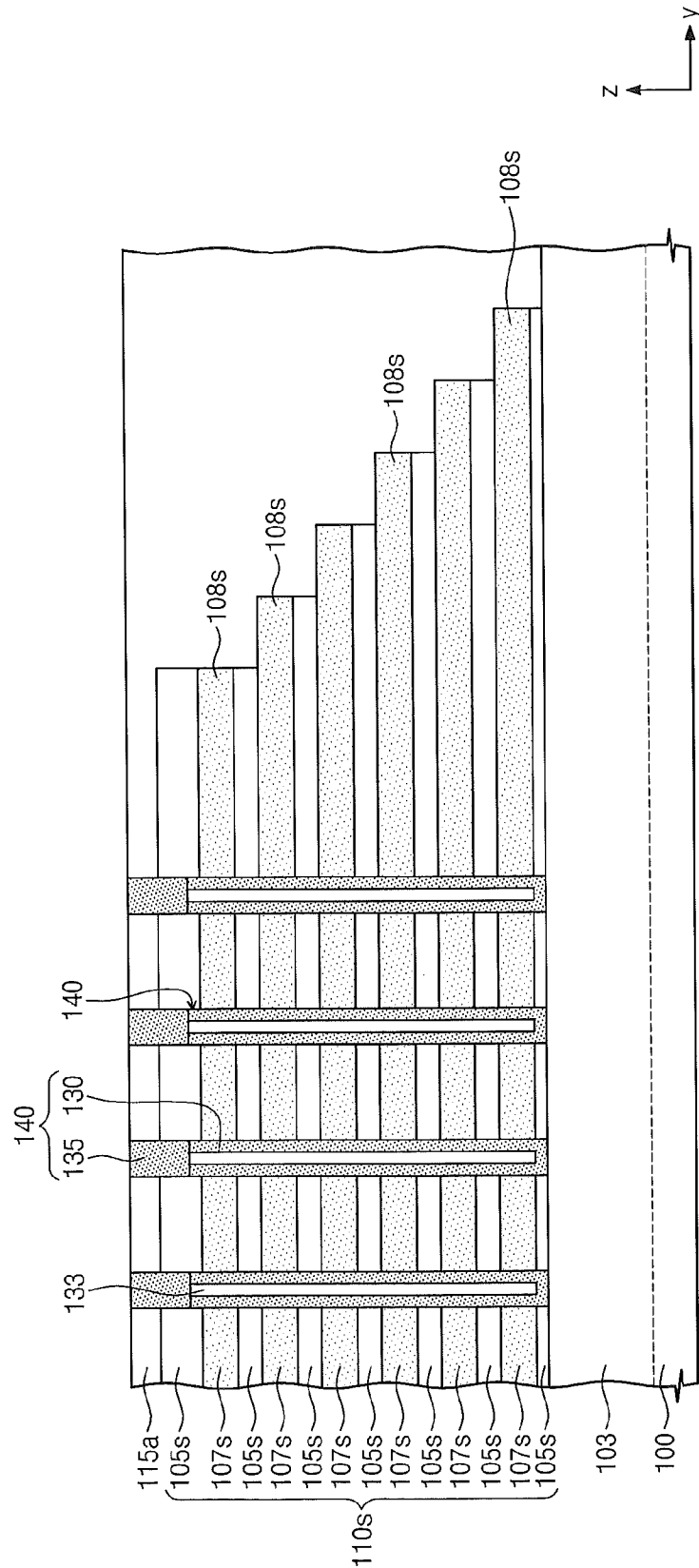


Fig. 5A

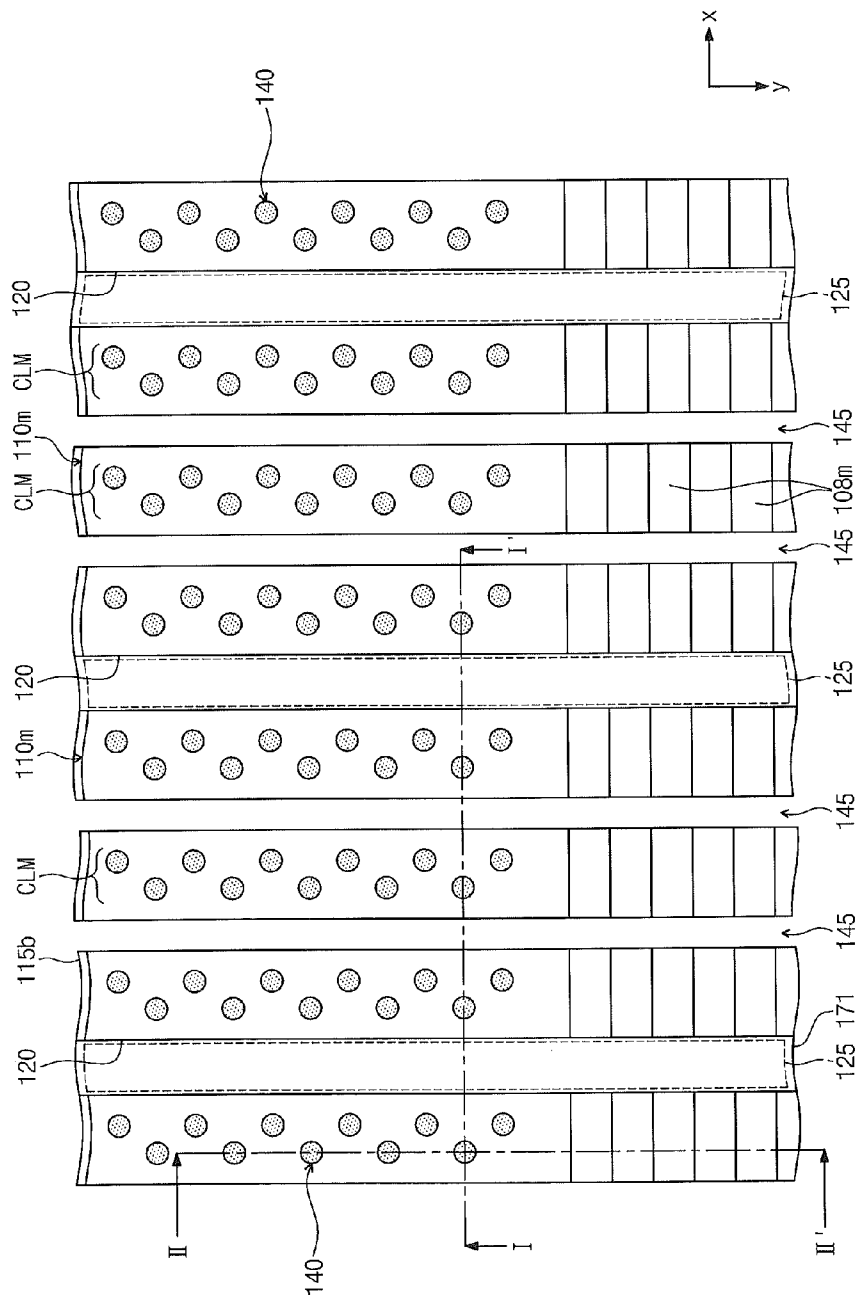
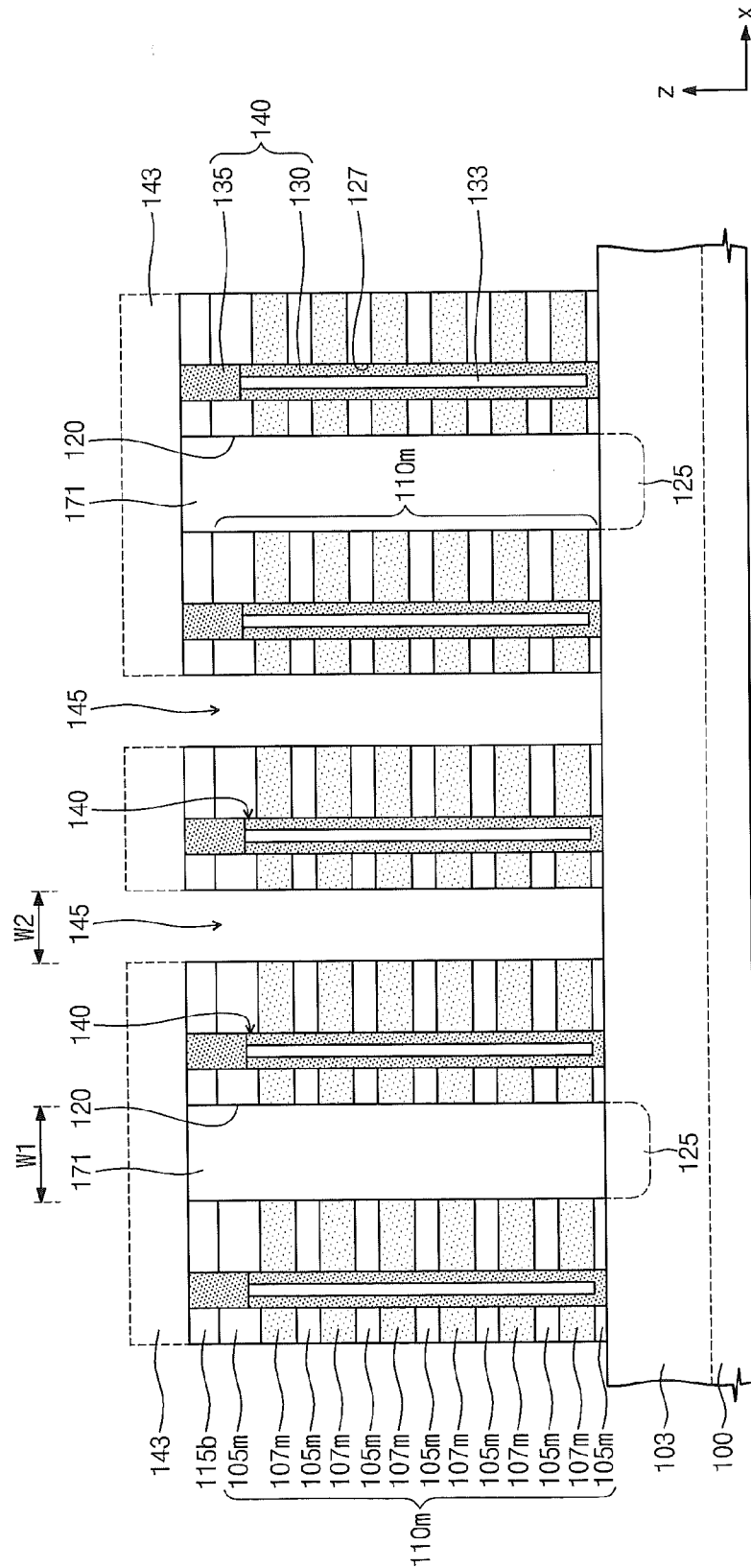


Fig. 5B



Fi. 50

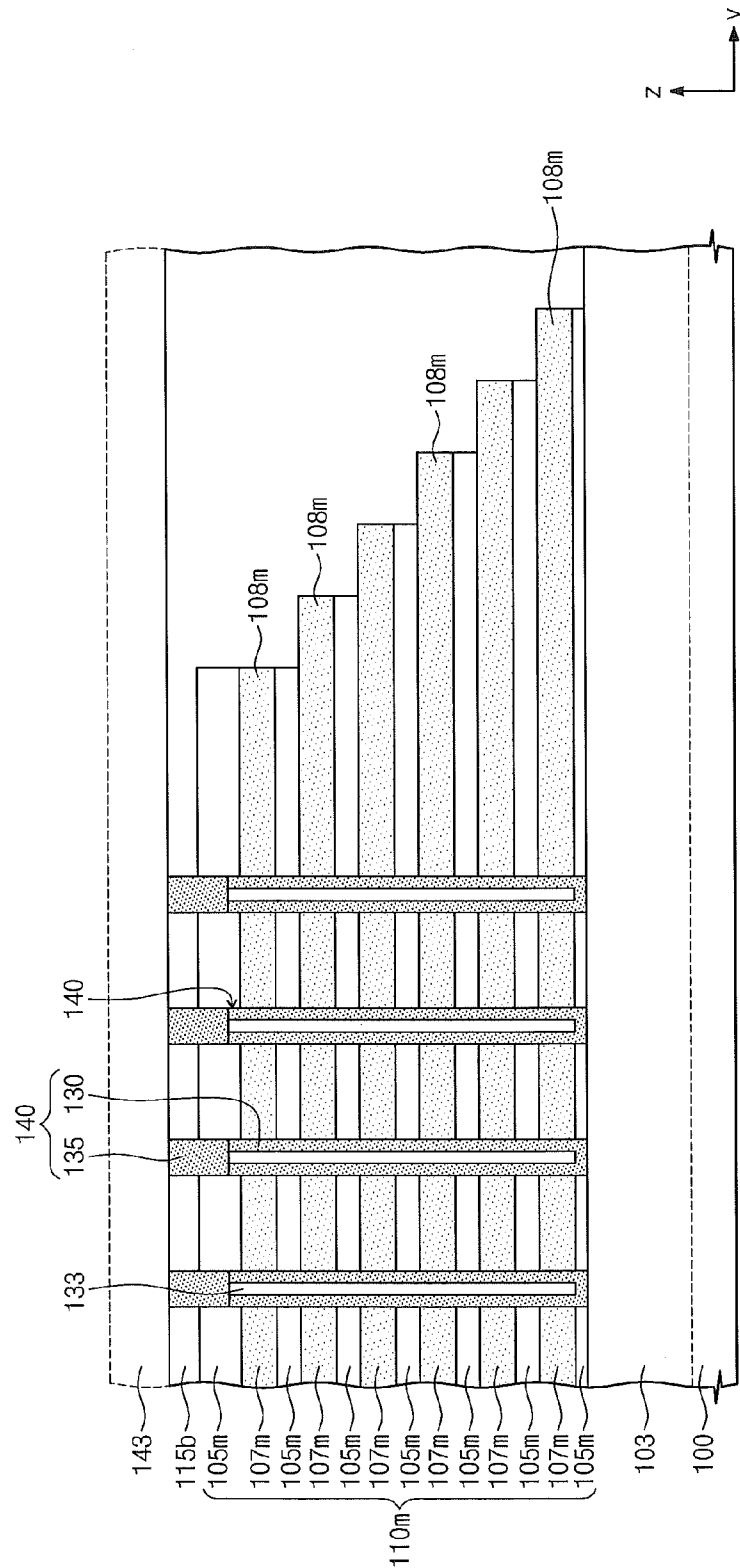




Fig. 6B

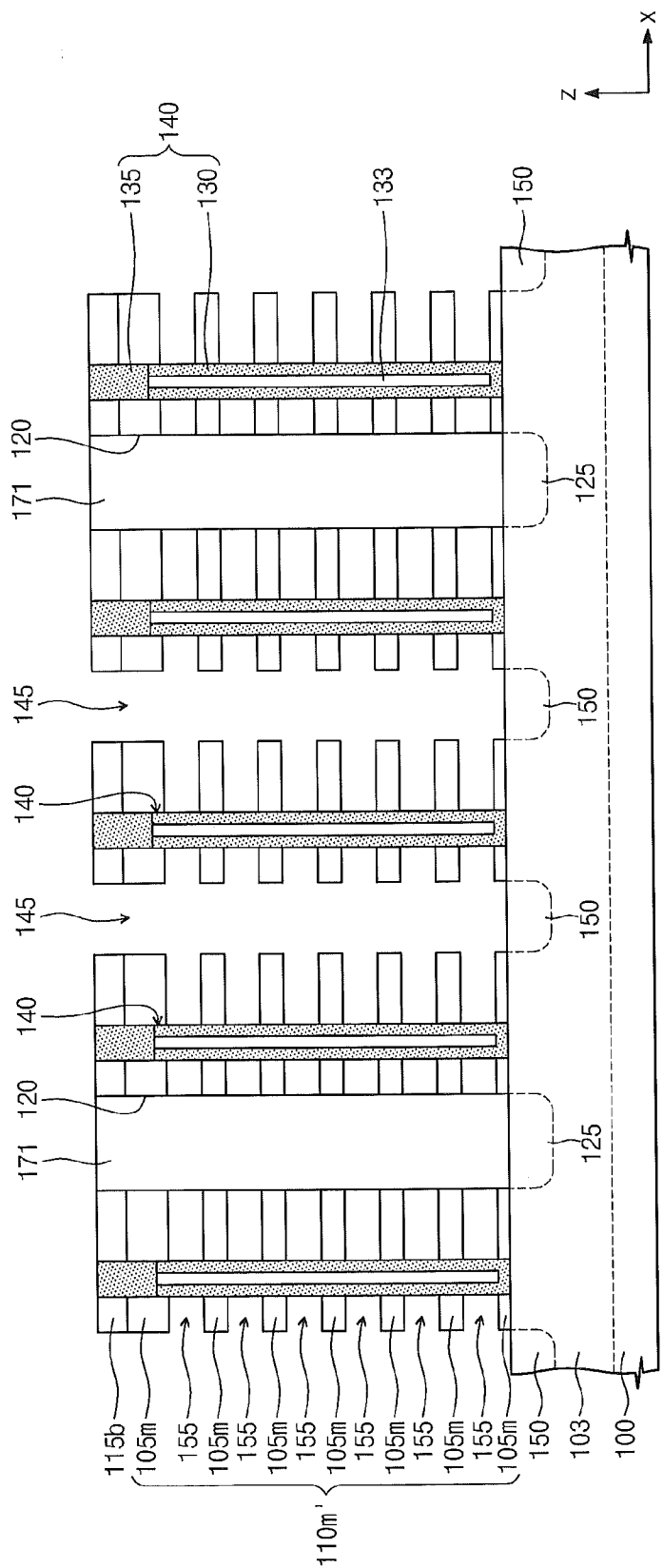


Fig. 6C

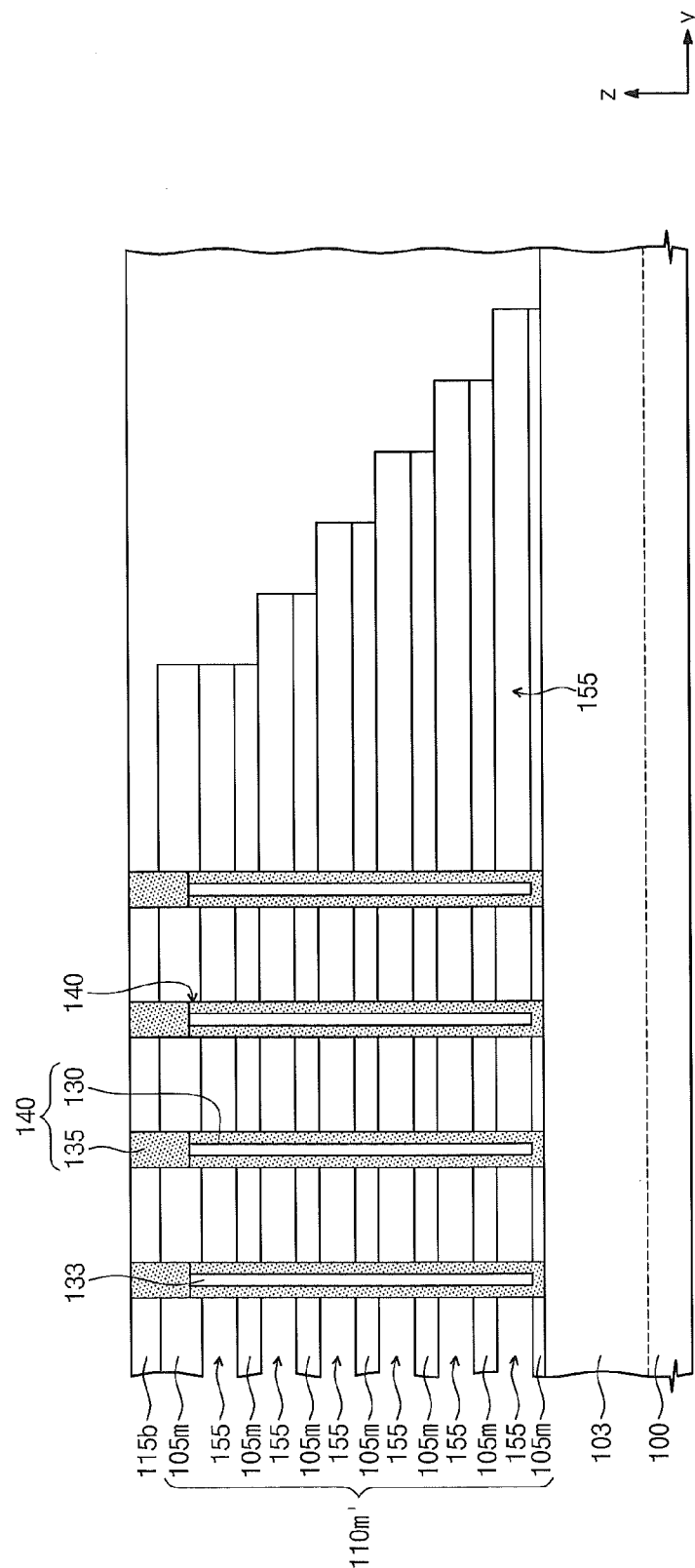
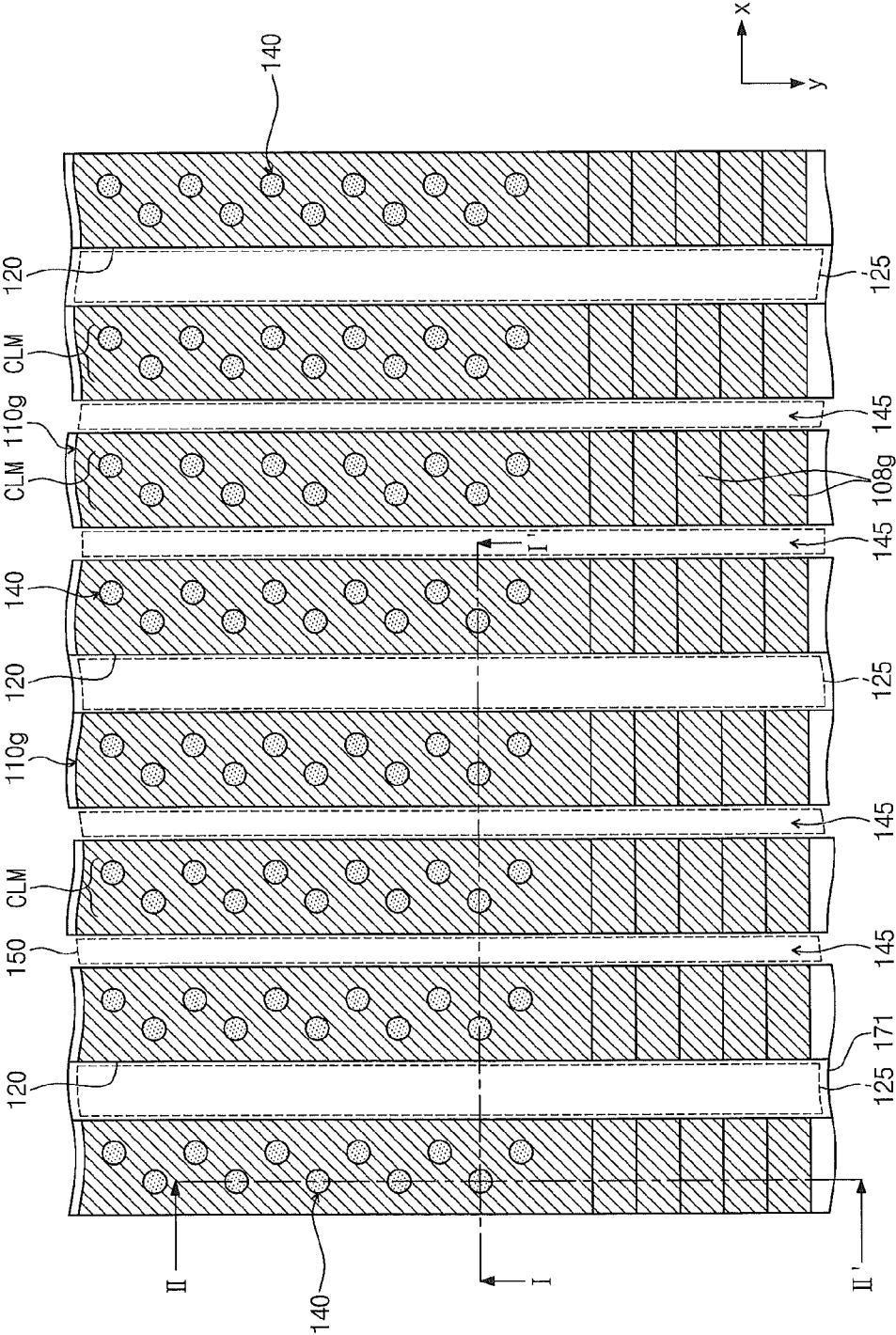


Fig. 7A



Fi. 2B

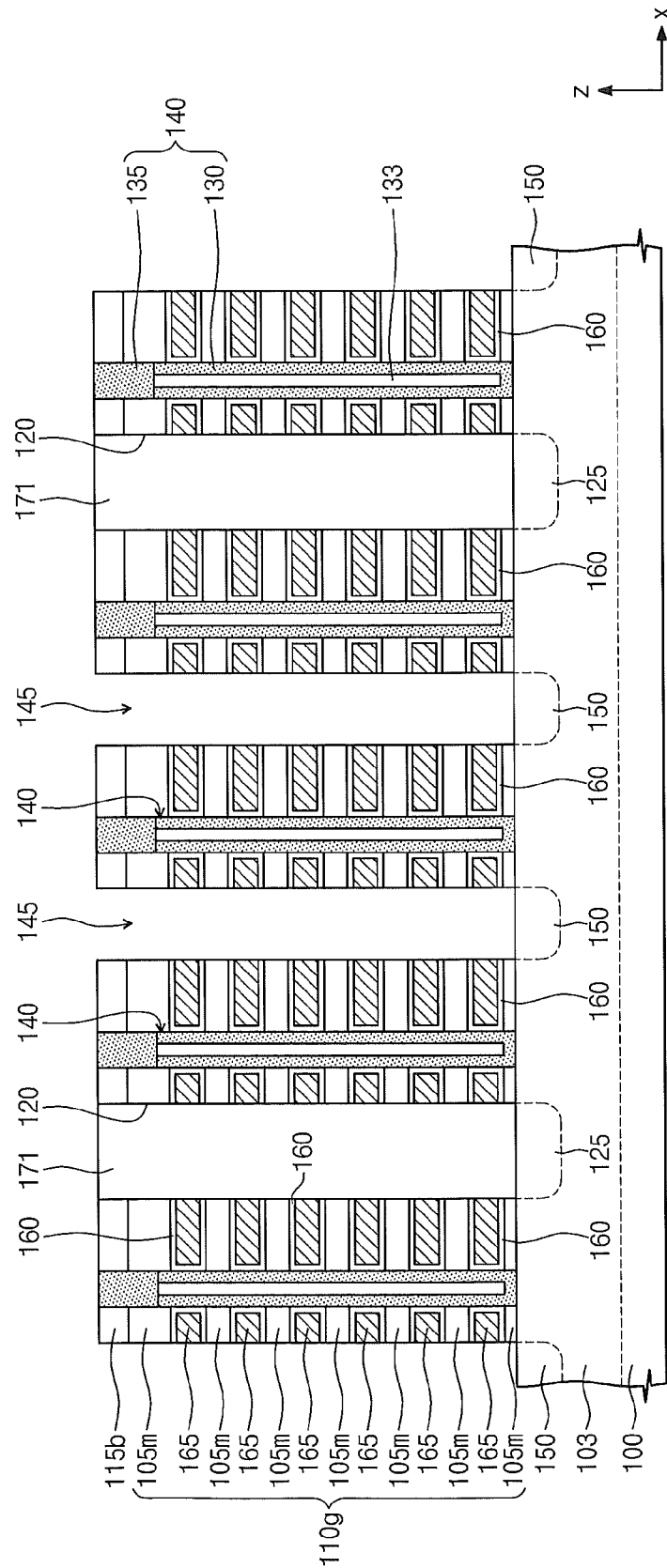


Fig. 20

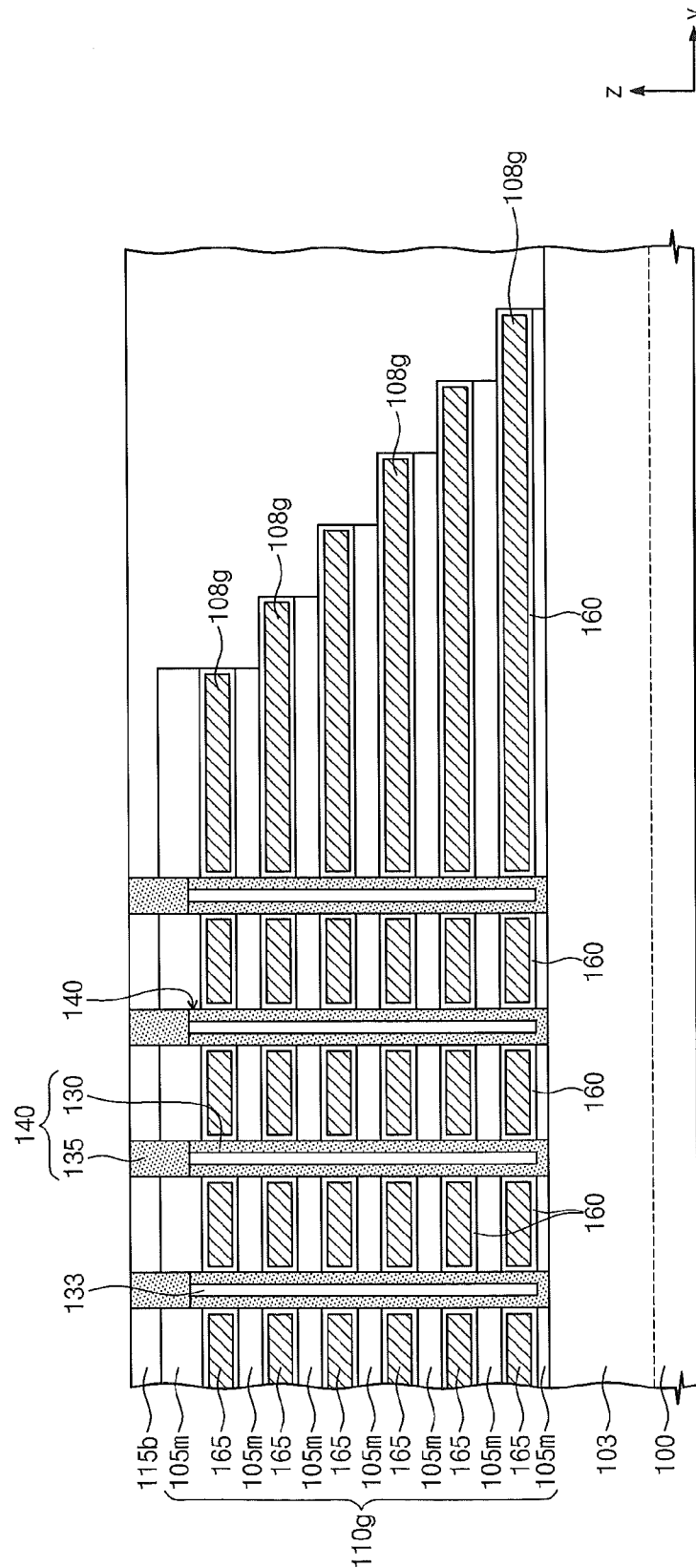


Fig. 8A

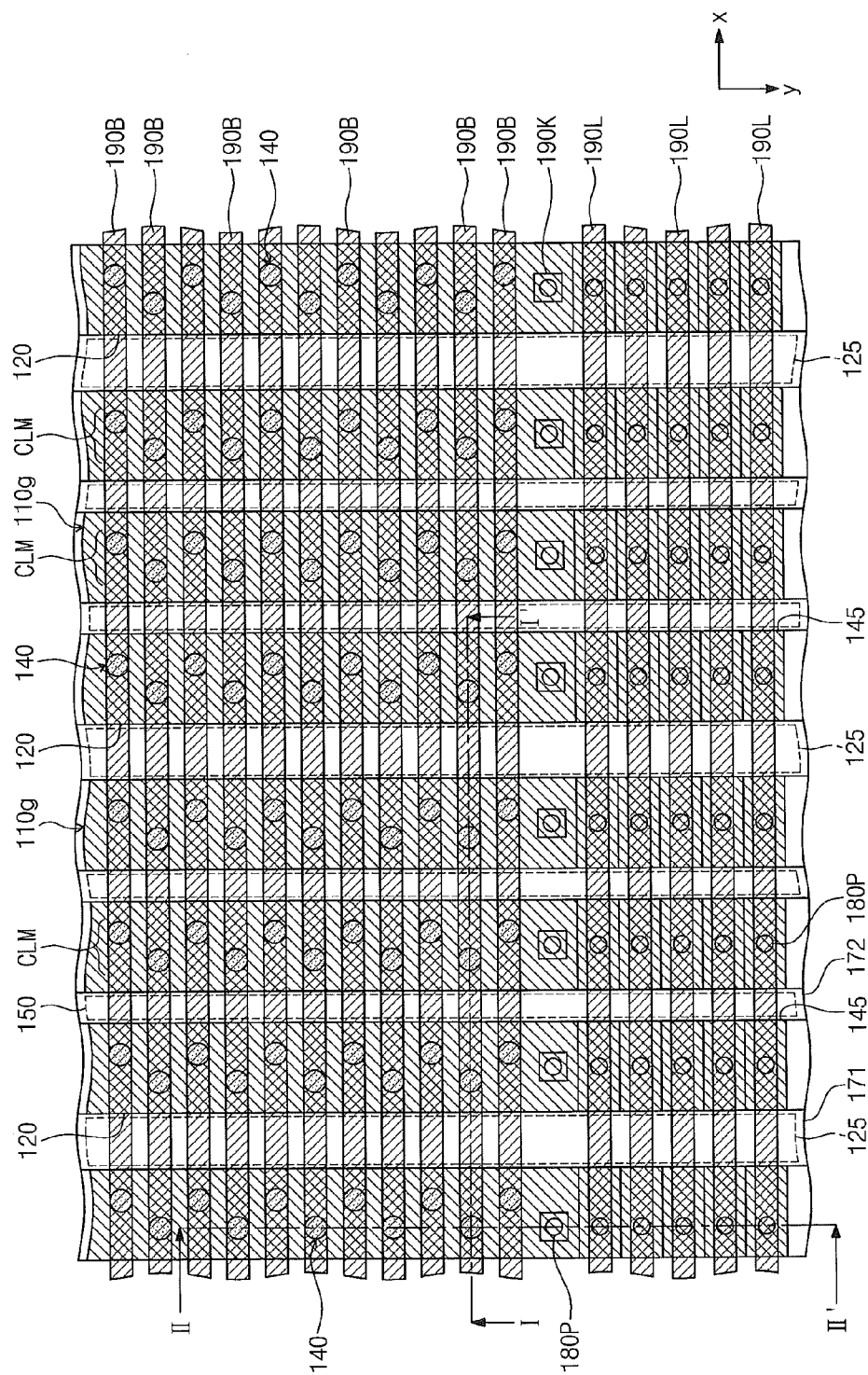
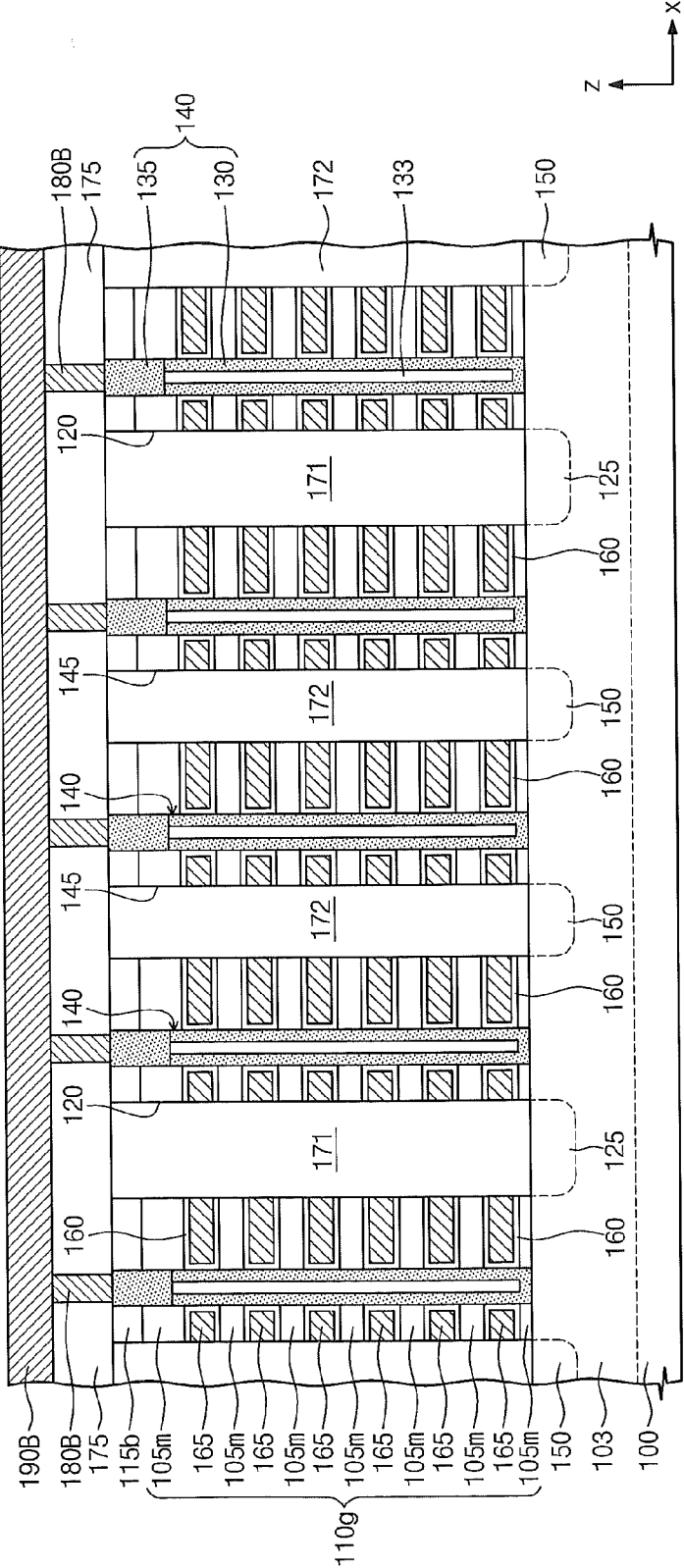


Fig. 8B



Fi. 80

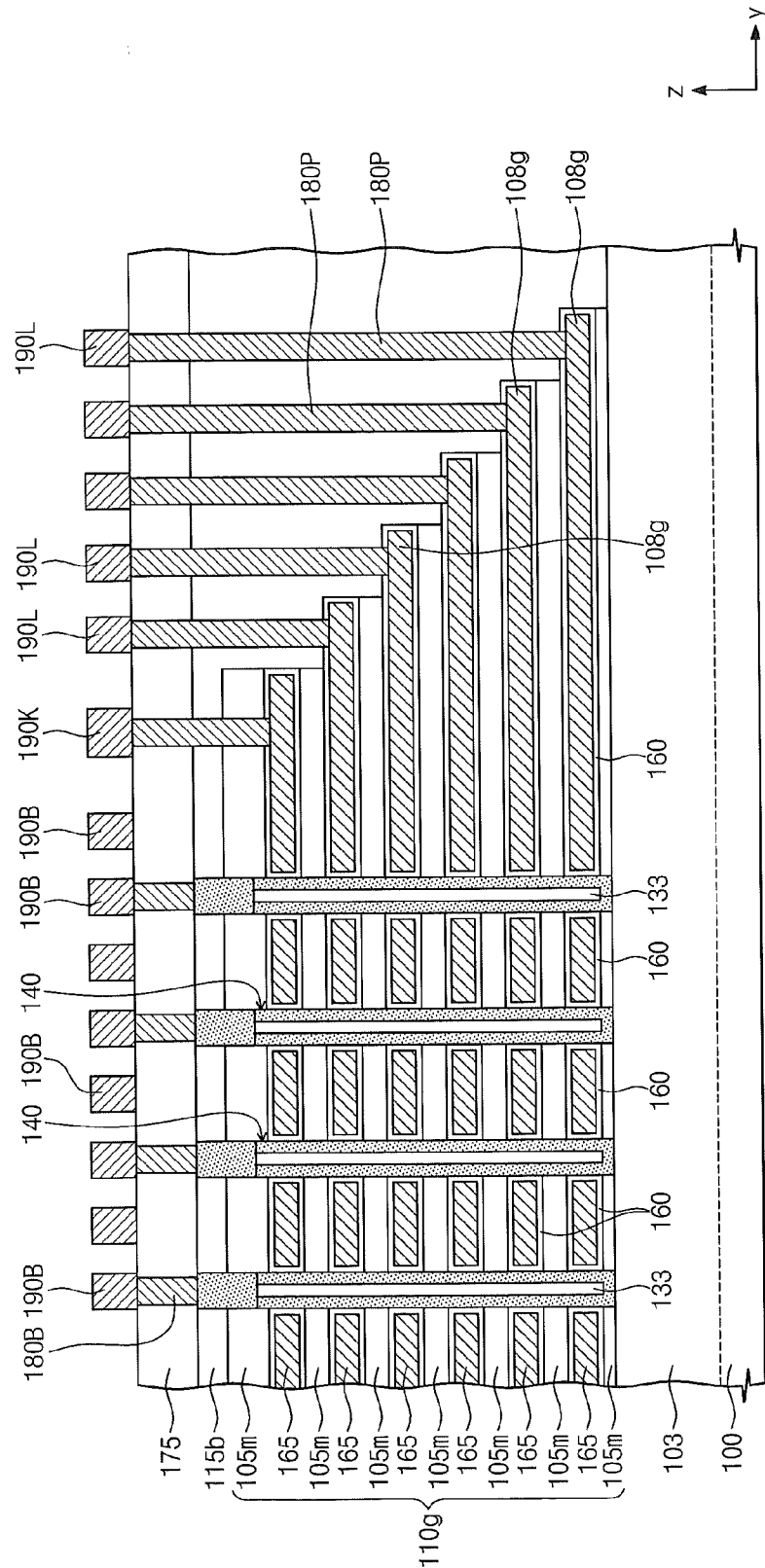


Fig. 9A

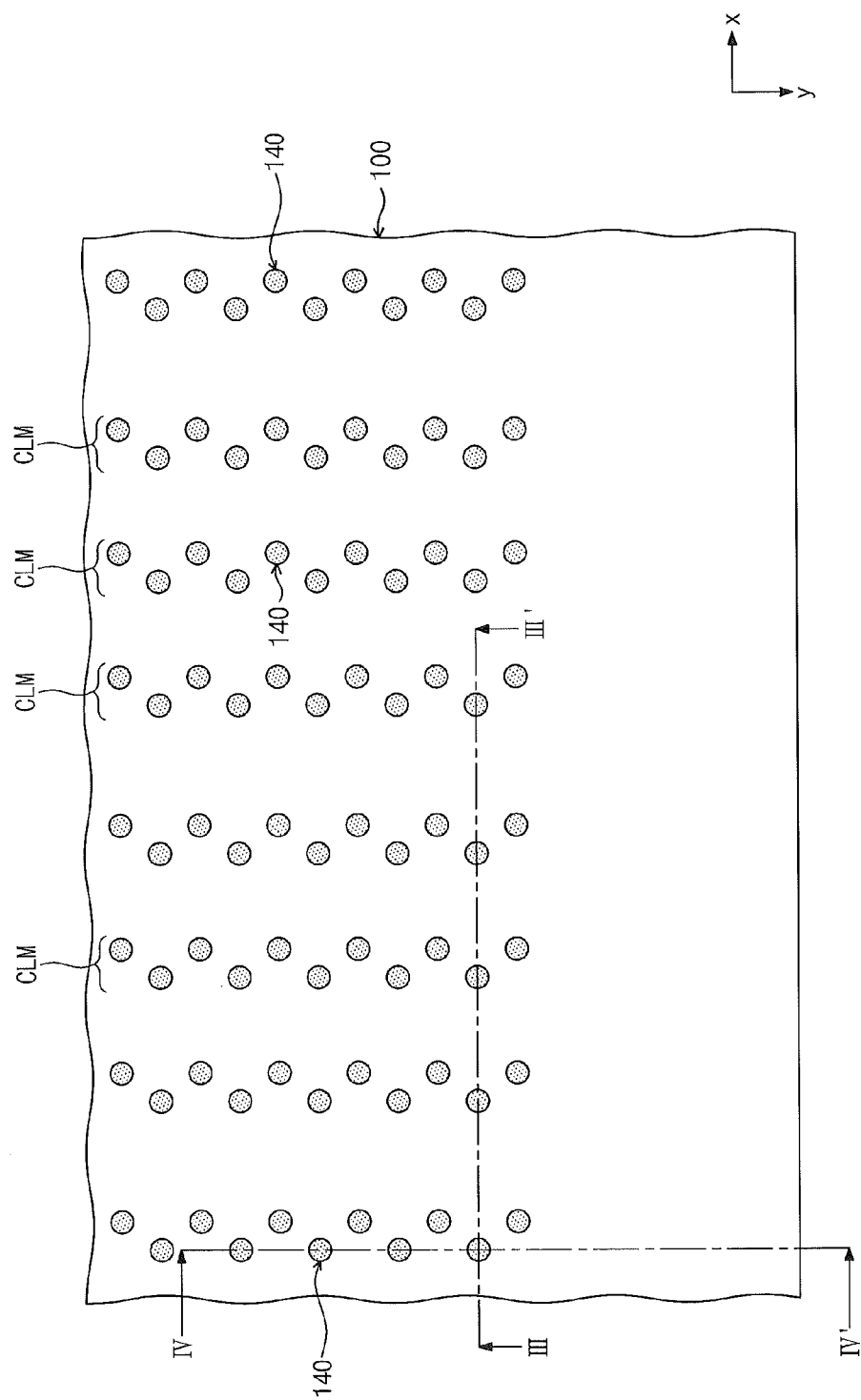


Fig. 9B

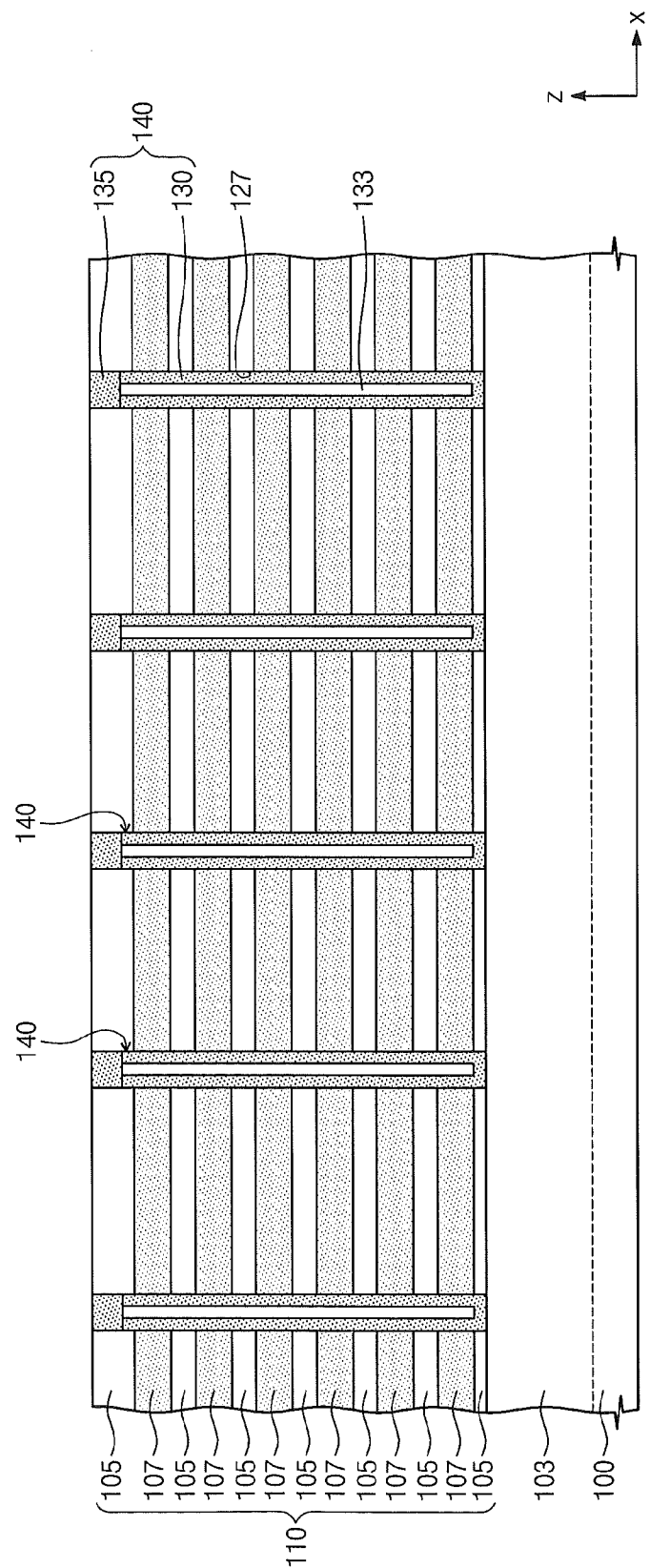


Fig. 9C

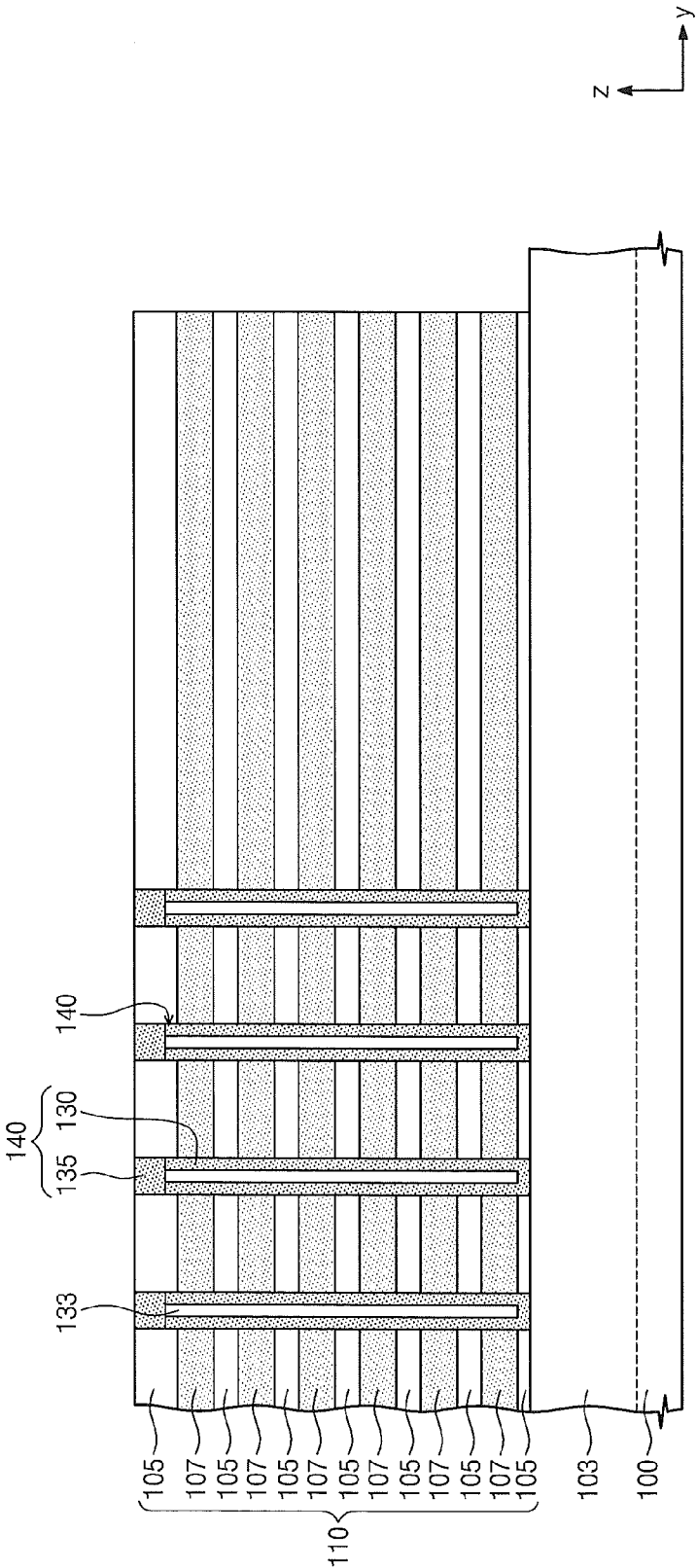


Fig. 10A

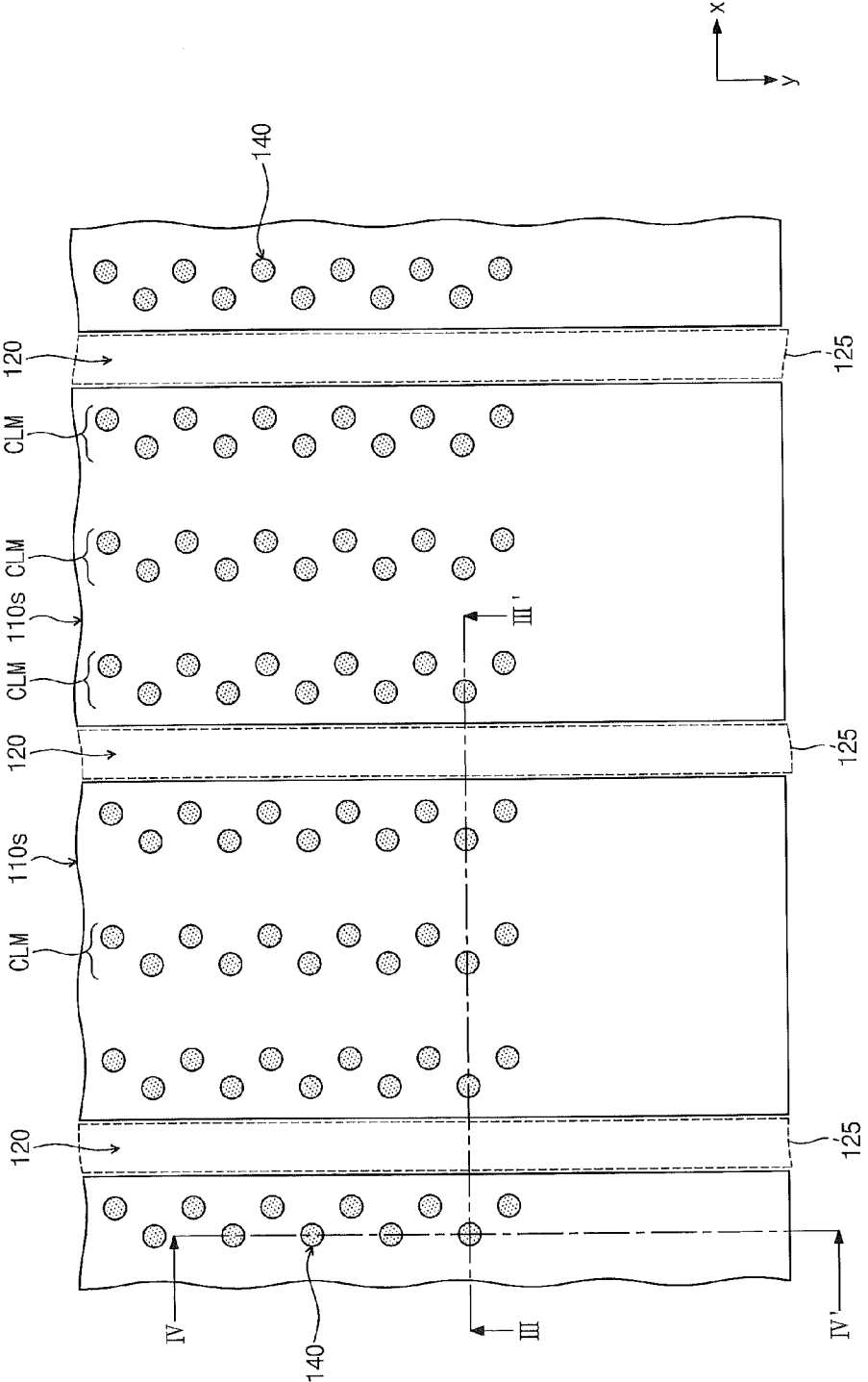


Fig. 10B

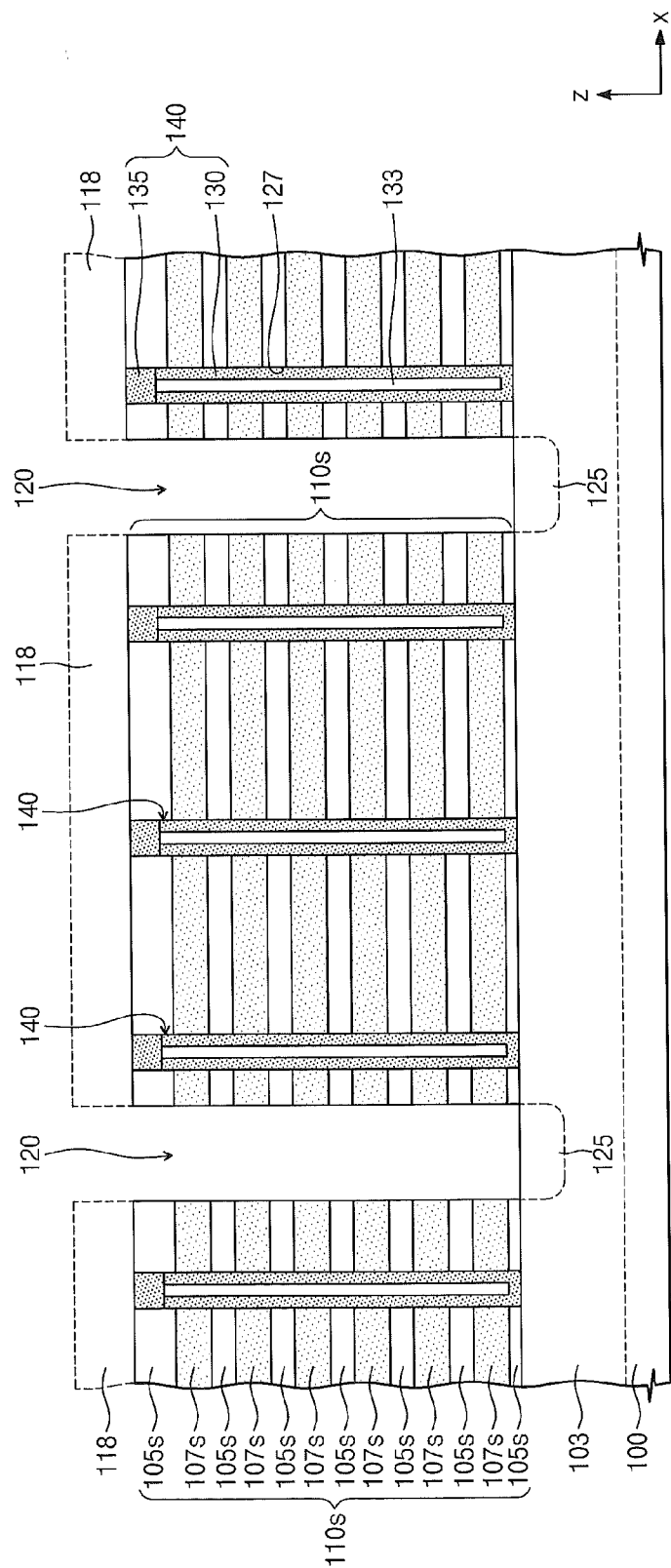


Fig. 10C

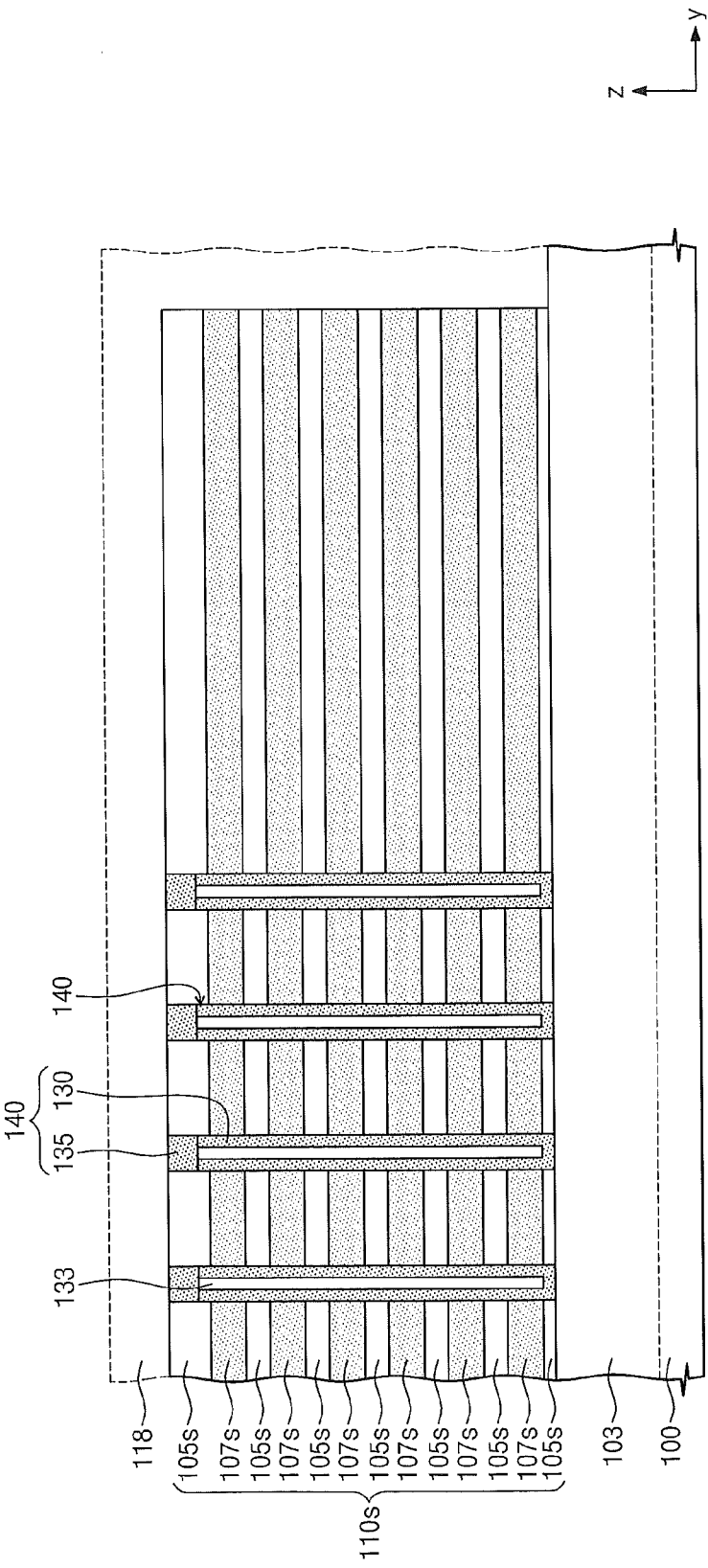


Fig. 11A

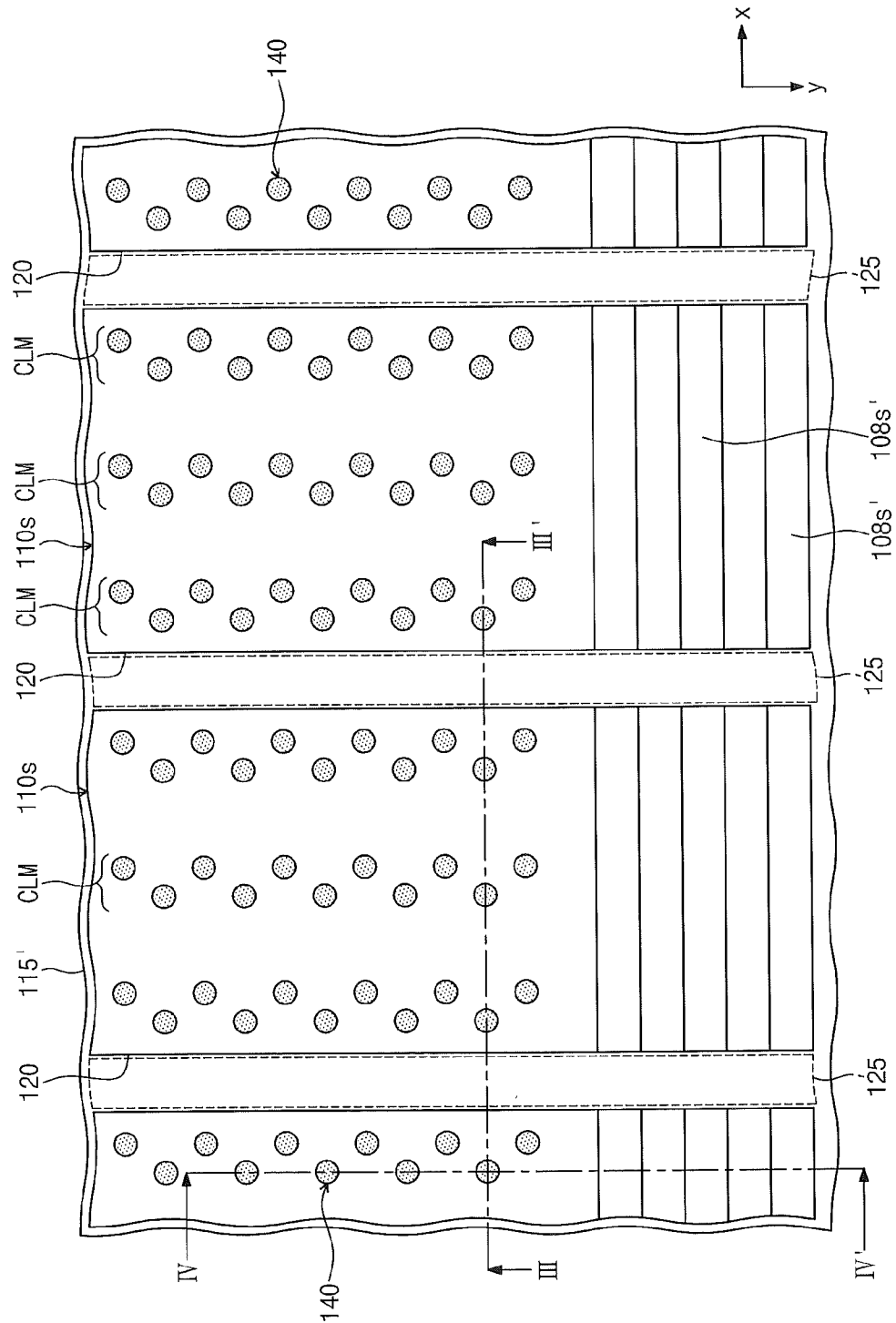


Fig. 11B

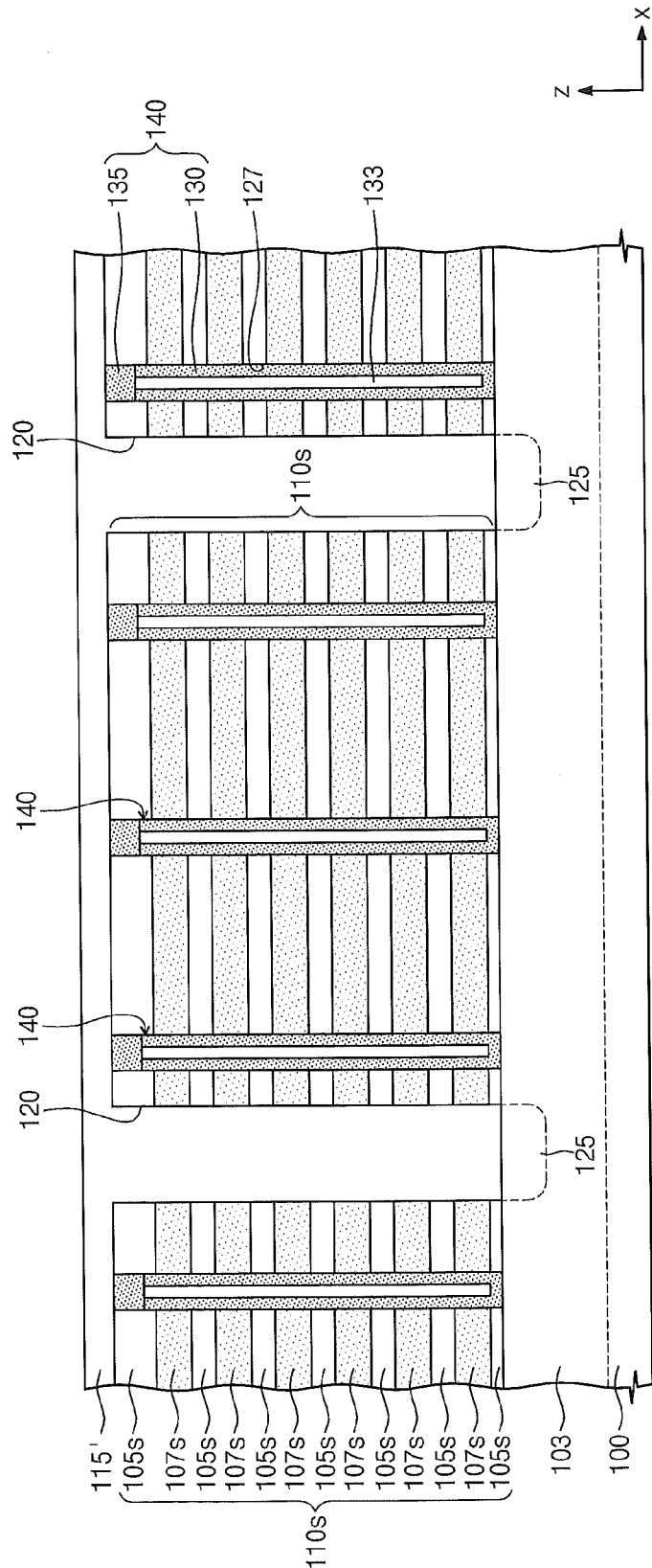


Fig. 11C

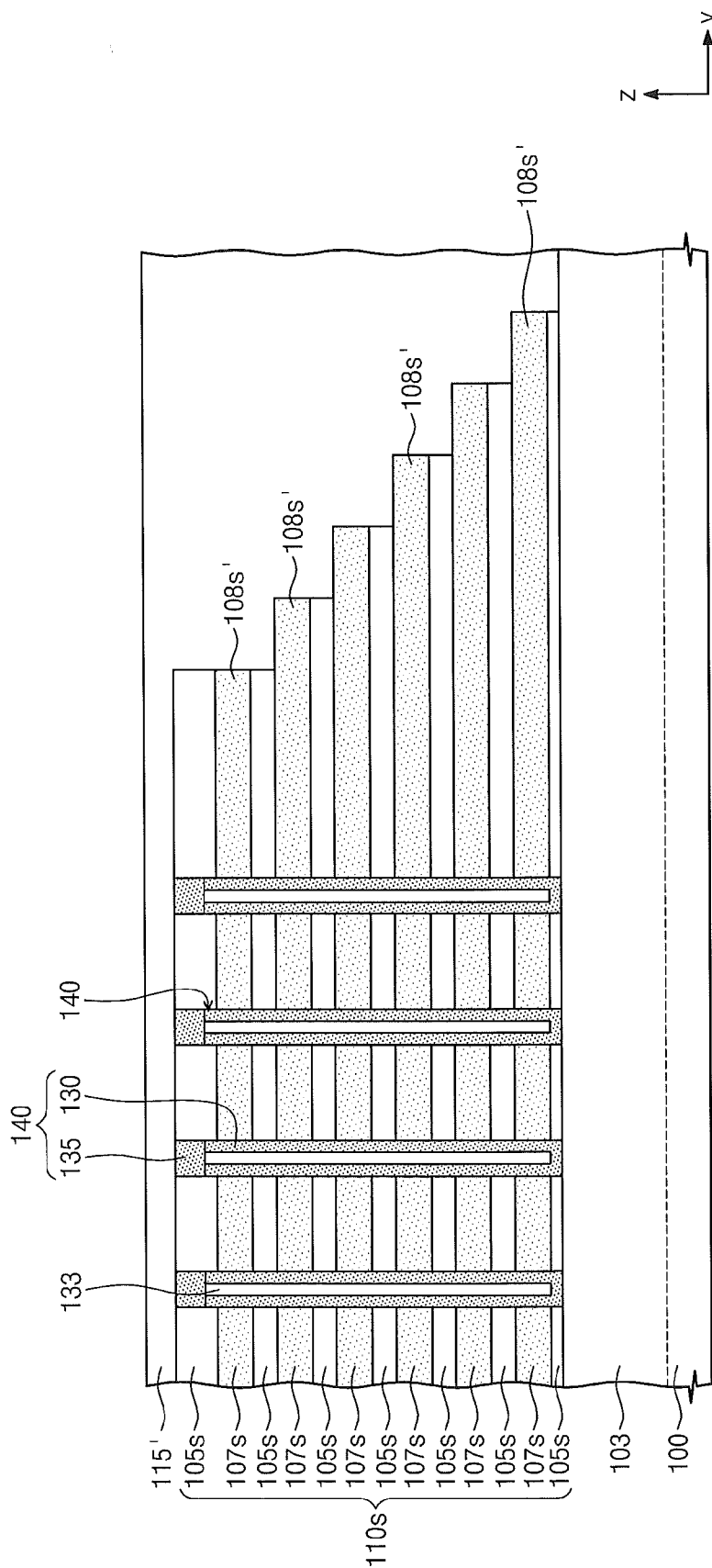


Fig. 12A

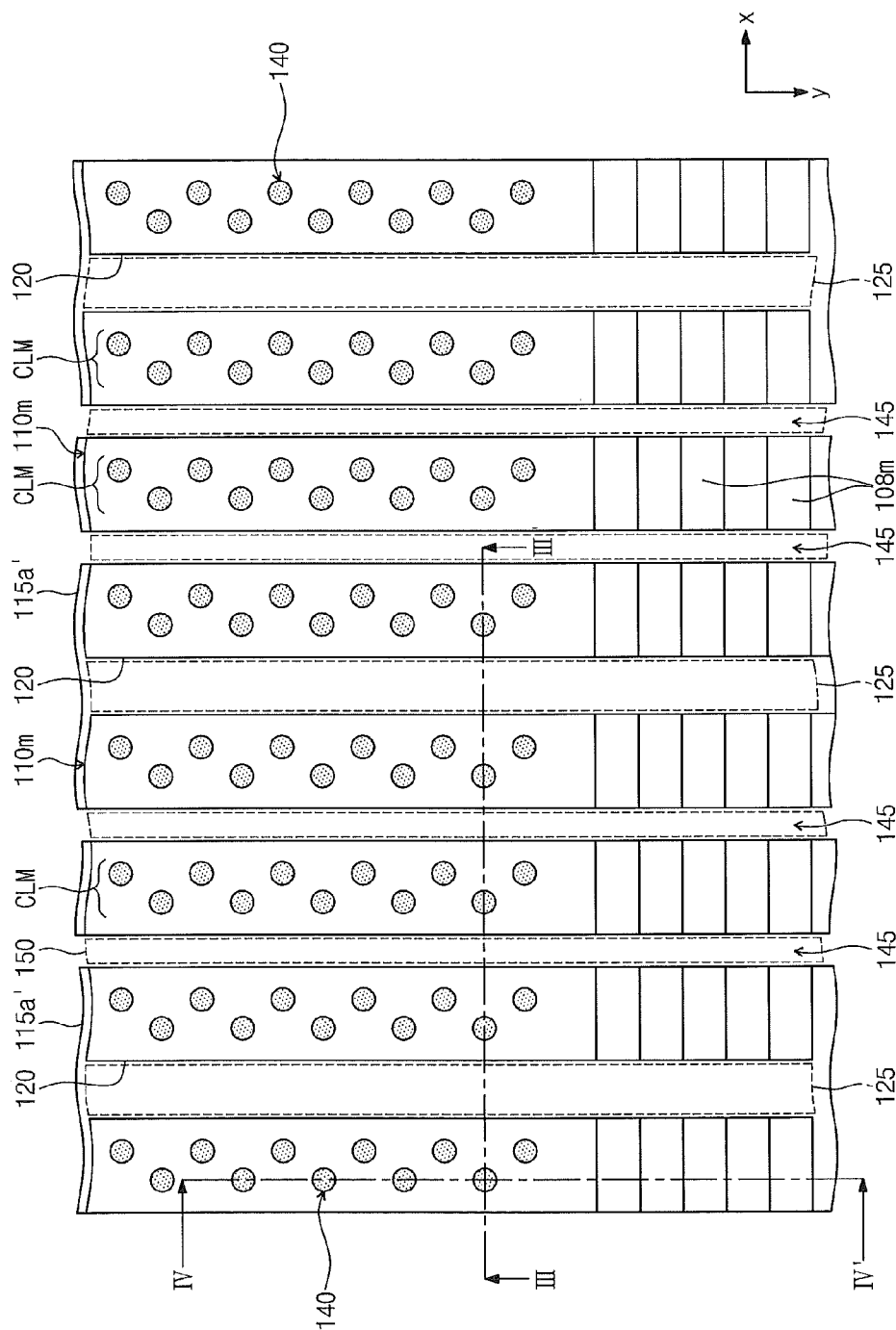


Fig. 12B

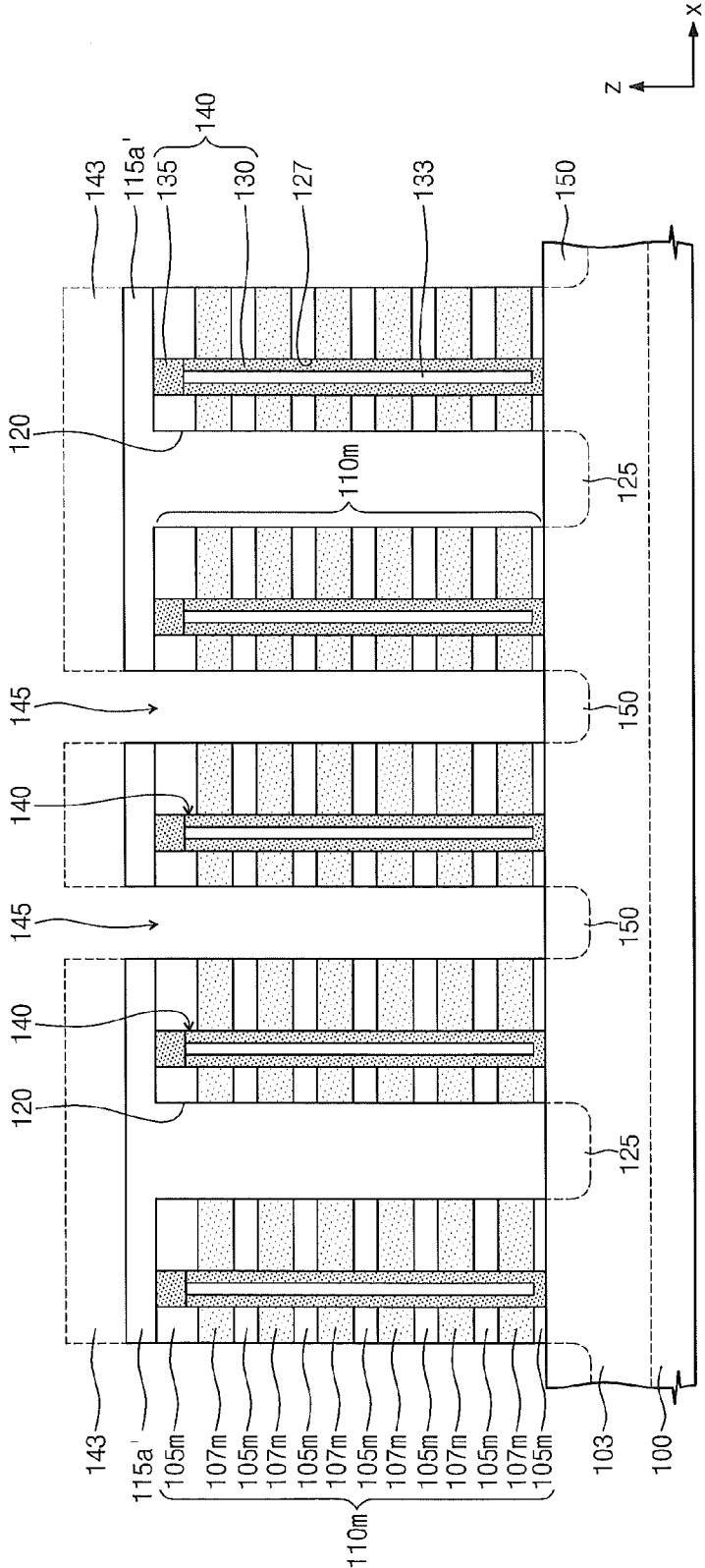
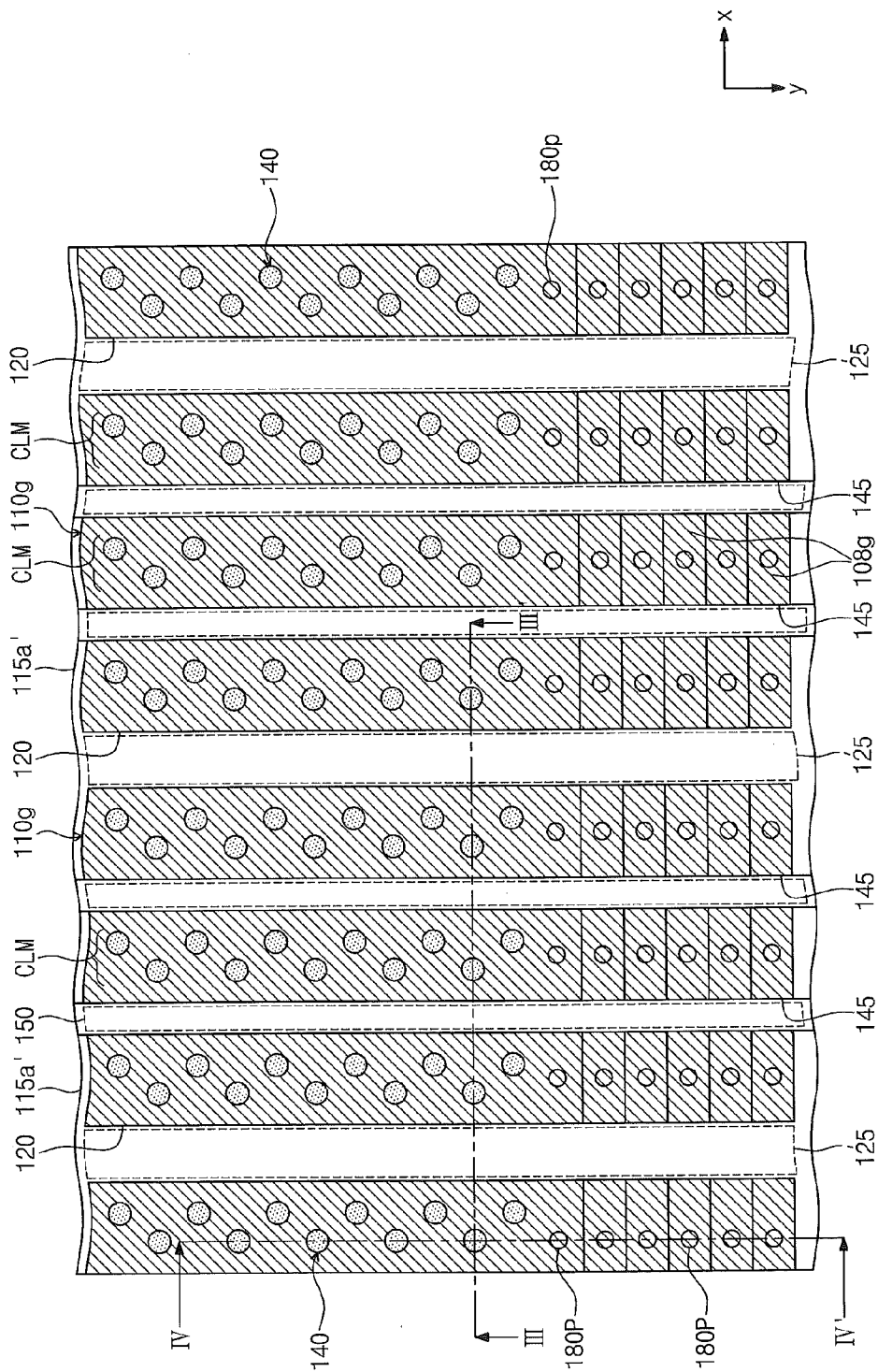




Fig. 13A







1

# METHODS OF MANUFACTURING THREE DIMENSIONAL SEMICONDUCTOR MEMORY DEVICES USING SUB-PLATES

## CROSS-REFERENCE TO RELATED APPLICATIONS

This U.S. non-provisional patent application claims priority under 35 U.S.C. §119 of Korean Patent Application No. 10-2010-0119904, filed on Nov. 29, 2010, the entire contents of which are hereby incorporated herein by reference.

## BACKGROUND

The present disclosure herein relates to a method of fabricating a semiconductor device, and more particularly, to a method of fabricating a Three Dimensional (3D) semiconductor memory device.

Generally, the surface area of a unit memory cell is a factor in determining a degree of integration of a semiconductor memory device. Due to this, a degree of integration of a semiconductor memory device may be affected by the ability of manufacturing technology to produce fine patterns.

## SUMMARY

Embodiments of the inventive concept may provide methods of manufacturing a Three Dimensional (3D) semiconductor memory device by forming a plate stack structure including a plurality of plate insulation patterns and plate sacrificial patterns which are stacked alternately and repeatedly on a substrate. Edges of the plate sacrificial patterns can be formed as pads included in a stepped structure. At least one first trench can be formed to divide the plate stack structure including the pads into a plurality of sub-plate stack structures. A plurality of vertical active patterns can be formed to pass through each of the sub-plate stack structures and at least one second trench can be formed to divide each of the sub-plate stack structures to provide a plurality of mold-stack structures.

In some embodiments according to the invention, the method can also include forming a capping dielectric layer which covers the pads, before the first trench is formed. The first trench can be formed by patterning the plate stack structure including the pads and the capping dielectric layer, where the sub-plate stack structure includes sub-pads providing a stepped structure that are divided from the pads of the plate sacrificial patterns. The second trench can be formed by patterning the sub-plate stack structure and a portion of the capping dielectric layer covering the sub-pads.

In some embodiments according to the invention, the mold-stack structure can include a plurality of mold insulation patterns and mold sacrificial patterns which are stacked alternately and repeatedly, where the mold sacrificial patterns can be removed to form a plurality of gap regions. A multi-layered dielectric layer can be formed on sidewalls of the plurality of gap regions and a plurality of gate patterns can be formed in the gap regions on the multi-layered dielectric layer.

In some embodiments according to the invention, a first isolation pattern can be formed to fill the first trench before the vertical active patterns are formed and a second isolation pattern can be formed to fill the second trench after the gate patterns are formed. In some embodiments according to the invention, the first and second trenches extend in a first direction and the first trench has a first width in a second direction perpendicular to the first direction. The second trench can

2

have a second width in the second direction and the first width can be different from the second width.

In some embodiments according to the invention, the vertical active patterns can pass through each of the sub-plate stack structures and are divided into a plurality of column groups, in a plan view. The second trench can be formed between a pair of the column groups that are adjacent to each other and the vertical active patterns in each of the column groups can pass through each of the mold-stack structures.

In some embodiments according to the invention, the vertical active patterns in the each of the column groups can be arranged in a first direction and odd-numbered vertical active patterns can be offset in a second direction, perpendicular to the first direction relative to even-numbered vertical active patterns.

In some embodiments according to the invention, a well region can be doped with a first conductive dopant, in the substrate. A first doped-region can be formed in a well region under the first trench and a second doped-region can be doped with a second conductive dopant, in a well region under the second trench. In some embodiments according to the invention, the first doped-region can be doped with the first conductive dopant and a dopant concentration of the first doped-region can be higher than a dopant concentration of the well region. In some embodiments according to the invention, the second doped-region is doped with the second conductive dopant.

In some embodiments according to the invention, a method of manufacturing a Three Dimensional (3D) semiconductor memory device can be provided by forming a plate stack structure that includes a plurality of plate insulation patterns and plate sacrificial patterns which are stacked alternately and repeatedly on a substrate. A plurality of vertical active patterns can be formed to pass through the plate stack structure. At least one first trench can be formed to divide the plate stack structure that includes the plurality of vertical active patterns, into a plurality of sub-plate stack structures, where each of the sub-plate stack structures can include a plurality of sub-plate insulation patterns and sub-plate sacrificial patterns which are stacked alternately and repeatedly. Edges of the sub-plate sacrificial patterns can be formed as pads of a stepped structure and at least one second trench can be formed to divide the respective sub-stack structures including the pads into a plurality of mold-stack structures.

In some embodiments according to the inventive concept, a method of manufacturing a Three Dimensional (3D) semiconductor memory device can be provided by forming at least one trench in a plate stack structure to divide the plate stack structure into a plurality of sub-plate stack structures between forming a plurality of vertical active patterns in the plate stack structure and forming pads of a stepped structure from the plate stack structure.

In some embodiments according to the invention, the plurality of vertical active patterns can be formed in the plate stack structure before forming the at least one trench in the plate stack structure. In some embodiments according to the invention, the pads of the stepped structure can be formed from the plate stack structure after forming the at least one trench in the plate stack structure.

In some embodiments according to the invention, the pads of the stepped structure can be formed from the plate stack structure before forming the at least one trench in the plate stack structure. In some embodiments according to the invention, the plurality of vertical active pattern can be formed in the plate stack structure after forming the at least one trench in the plate stack structure.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A to 8A are a plan views illustrating methods of manufacturing a 3D semiconductor memory device according to an embodiment of the inventive concept.

FIGS. 1B to 8B are sectional views taken along line I-I' of FIGS. 1A to 8A, respectively.

FIGS. 1C to 8C are sectional views taken along line II-II' of FIGS. 1A to 8A, respectively;

FIGS. 9A to 13A are a plan views illustrating methods of manufacturing a 3D semiconductor memory device according to another embodiment of the inventive concept.

FIGS. 9B to 13B are sectional views taken along line III-III' of FIGS. 9A to 13A, respectively.

FIGS. 9C to 13C are sectional views taken along line IV-IV' of FIGS. 9A to 13A, respectively.

## DETAILED DESCRIPTION

Exemplary embodiments of the inventive concept will be described below in more detail with reference to the accompanying drawings. The inventive concept may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art.

In the specification, it will be understood that when an element such as a layer, film, region, or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. In the figures, the dimensions of layers and regions are exaggerated for clarity of illustration. Also, though terms like a first, a second, and a third are used to describe various regions and layers in various embodiments of the present invention, the regions and the layers are not limited to these terms. These terms are used only to discriminate one region or layer from another region or layer. Therefore, a layer referred to as a first layer in one embodiment can be referred to as a second layer in another embodiment. An embodiment described and exemplified herein includes a complementary embodiment thereof. In the specification, the term 'and/or' is used as meaning in which the term includes at least one of preceding and succeeding elements. Like reference numerals refer to like elements throughout.

(First Embodiment)

FIGS. 1A to 8A are a plan views illustrating a method of manufacturing a 3D semiconductor memory device according to an embodiment of the inventive concept. FIGS. 1B to 8B are sectional views taken along line I-I' of FIGS. 1A to 8A, respectively. FIGS. 1C to 8C are sectional views taken along line II-II' of FIGS. 1A to 8A, respectively.

Referring to FIGS. 1A to 1C, a well region 103 may be formed by providing a first conductive dopant in a semiconductor substrate 100 (hereinafter referred to as a substrate). The substrate 100 may be a silicon substrate, a germanium substrate, or a silicon-germanium substrate. A plate stack structure 110 may be formed on the substrate 100. The plate stack structure 110 may include a plurality of plate insulation patterns 105 and plate sacrificial patterns 107 that are stacked alternately and repeatedly on the substrate 100. The plate stack structure 110 may be formed on the well region 103. The plate sacrificial patterns 107 may include a material having an etch selectivity with respect to the plate insulation patterns 105. For example, if the plate insulation patterns 105 are formed of oxide, the plate sacrificial patterns 107 may be formed of nitride. A plurality of insulation layers and a plu-

ality of sacrificial layers may be alternately and repeatedly stacked on the substrate 100, and thereafter, the stacked insulation layers and sacrificial layers may be patterned to form the plate stack structure 110. Therefore, as illustrated in FIG. 1C, the patterns 105 and 107 in the plate stack structure 110 may have sidewalls that are aligned with each other.

A plurality of pads having a stepped structure may be formed at an edge of the plate stack structure 110. According to an embodiment of the inventive concept, a pad mask pattern 113 may be formed on the plate stack structure 110. The pad mask pattern 113 may define a pad of a lowermost plate sacrificial pattern of the plate sacrificial patterns 107 in the plate stack structure 110.

Referring to FIGS. 1A to 1C and 2A to 2C, edges of the plate insulation patterns 105 and plate sacrificial patterns 107 disposed on the lowermost plate sacrificial pattern may be etched using the pad mask pattern 113 as an etch mask. Therefore, an edge of the lowermost plate sacrificial pattern may be exposed. The exposed edge of the lowermost plate sacrificial pattern may correspond to a pad 108 of the lowermost plate sacrificial pattern.

The pad mask pattern 113 may be isotropic-etched. A sidewall of the pad mask pattern 113 may be laterally etched by the isotropic etching. Therefore, the isotropic-etched pad mask pattern may define a pad of a plate sacrificial pattern that is second from a top surface of the substrate 100. Plate insulation patterns 105 and plate sacrificial patterns 107 disposed on the secondary stacked plate sacrificial pattern may be etched using the isotropic-etched pad mask pattern as an etch mask. Therefore, an edge of the secondary stacked plate sacrificial pattern may be exposed. The edge of the secondary stacked plate sacrificial pattern corresponds to a pad 108 of the secondary stacked plate sacrificial pattern. Such an isotropic etching process for the pad mask pattern and an etching process (which uses the isotropic-etched pad mask pattern as an etch mask) for the plate insulation pattern 105 and the plate sacrificial pattern 107 may be performed repeatedly. Therefore, the plate sacrificial patterns 107 may be formed to have pads 108 constituting a stepped structure. In other words, the pads 108 providing the stepped structure may be formed using the pad mask pattern 113 as a consumptive mask.

As disclosed in FIGS. 2A and 2C, the pads 108 of the plate sacrificial patterns 107 may have a downwardly stepped structure in a first direction. In a plan view, the pads 108 of the plate sacrificial patterns 107 may be extended side by side in a second direction perpendicular to the first direction. The first direction may correspond to a y axis in FIG. 2A, and the second direction may correspond to an x axis in FIG. 2A.

After formation of the pads 108 providing the stepped structure, any remaining portion of the pad mask pattern may be removed.

Subsequently, a capping dielectric layer 115 may be formed on the substrate 100. According to FIG. 2C, the capping dielectric layer 115 may cover the pads 108 of the stepped structure. The capping dielectric layer 115 may include a dielectric material having an etch selectivity with respect to the plate sacrificial patterns 107. For example, when the plate sacrificial patterns 107 are formed of nitride, the capping dielectric layer 115 may be formed of oxide.

The capping dielectric layer 115 may be deposited by a Chemical Vapor Deposition (CVD) process. To minimize a step height due to the pads 108 of the stepped structure 108, a top surface of the capping dielectric layer 115 may be planarized. According to an embodiment of the inventive concept, as disclosed in FIGS. 2B and 2C, the planarized top surface of the capping dielectric layer 115 may be higher than the uppermost surface of the plate stack structure 110. There-

5

fore, the capping dielectric layer **115** may cover the uppermost surface (for example, a top surface of the uppermost plate insulation pattern) of the plate stack structure **110**. However, the inventive concept is not limited thereto. The capping dielectric layer **115** may be planarized until the uppermost surface of the plate stack structure **110** is exposed. Even in this case, the capping dielectric layer **115** may cover the pads **108**. In the following description, for convenience, it is assumed that the capping dielectric layer **115** covers the uppermost surface of the plate stack structure **110**.

Referring to FIGS. 3A to 3C, at least one first trench **120** is formed to divide the plate stack structure **110** into a plurality of sub-plate stack structures **110s** by patterning the plate stack structure **110** and the capping dielectric layer **115**.

According to FIGS. 3B and 3C, a first mask pattern **118** (which is illustrated as a dotted line) having a first opening may be formed on the plate stack structure **110** and the capping dielectric layer **115**. The first opening may define the first trench **120**. The stacked plate insulation patterns **105** and the plate sacrificial patterns **107** may be sequentially etched using the first mask pattern **118** as an etch mask, and thus the first trench **120** may be formed. Each of the sub-plate stack structures **110s** may include the sub-plate insulation patterns **105s** and the sub-plate sacrificial patterns **107s** that are stacked alternately and repeatedly. According to FIG. 3A, the first trench **120** may be extended in the first direction and cross the pads **108** of the plate stack structure **110**. Therefore, the first trench **120** divides the pads **108** of the plate stack structure **110**. As a result, according to FIGS. 3A and 3C, each of the sub-plate stack structures **110s** may have sub-pads **108s** constituting a stepped structure. The sub-pads **108s** of the respective sub-plate stack structures **110s** may correspond to the respective edges of sub-plate sacrificial patterns **107s** in the respective sub-plate stack structures **110s**. The sub-pads **108s** may be covered by the capping dielectric pattern **115a** that is formed by the first trench **120**.

In some embodiments of the inventive concept, a first doped-region **125** may be formed in a well region **103** under the first trench **120**. In some embodiments of the inventive concept, the first doped-region **125** may be doped with a dopant having the same type as that of the well region **103**, i.e., the first conductive dopant. A first conductive dopant concentration in the first doped-region **125** may be higher than a first conductive dopant concentration of the well region **103**. In this case, a stable well voltage may be supplied to the well region **103** through the first doped-region **125**. However, the inventive concept is not limited thereto.

In some embodiments of the inventive concept, the first doped-region **125** may be doped with a second conductive dopant. One of the first and second conductive dopants is an n-type dopant, and the other is a p-type dopant. Therefore, the first doped-region **125** and the well region **103** may form a PN junction. According to still another embodiment of the inventive concept, the first doped-region **125** may not be formed.

Referring to FIGS. 4A to 4C, a first isolation pattern **171** filling the first trench **120** may be formed. For example, a first isolation layer filling the first trench **120** may be formed on the substrate **100** and then the first isolation layer may be planarized, thereby forming the first isolation pattern **171**. The first isolation pattern **171** may include oxide.

A plurality of vertical active patterns **140** passing through each of the sub-plate stack structures **110s** may be formed. For example, a plurality of channel holes **127** may be formed, which pass through the capping dielectric pattern **115a** on each of the sub-plate stack structures **110s** and each of the sub-plate stack structures **110s**. A semiconductor layer may be conformally formed on the substrate **100** having the chan-

6

nel holes **127**, and a filling dielectric layer may fill the channel holes **127**. The filling dielectric layer and the semiconductor layer may be planarized to form the vertical semiconductor pattern **130** and a filling dielectric pattern **133** in the respective channel holes **127**. The upper ends of the vertical semiconductor pattern **130** and filling dielectric pattern **133** may be recessed lower than an upper end of the channel hole **127**. A capping semiconductor layer filling the channel hole **127** on the vertical semiconductor pattern **130** may be formed on the substrate **100**. A capping semiconductor pattern **135** may be formed by planarizing the capping semiconductor layer. The capping semiconductor pattern **135** may be confined to the channel hole **127**. The vertical semiconductor pattern **130** and the capping semiconductor pattern **135** in the respective channel holes **127** may constitute the vertical active pattern **140**. A drain region may be formed by providing the second conductive dopant to an upper portion of the vertical active pattern **140**.

The vertical semiconductor pattern **130** and the capping semiconductor pattern **135** may include the same semiconductor element as that of the substrate **100**. For example, when the substrate **100** is a silicon substrate, the vertical semiconductor pattern **130** and the capping semiconductor pattern **135** may include silicon. The vertical semiconductor pattern **130** and the capping semiconductor pattern **135** may be in a crystalline state.

According to FIG. 4A, a plurality of vertical active patterns **140** passing through the respective sub-plate stack structures **110s** may be divided into a plurality of column groups CLM. The vertical active patterns **140** in the respective column groups CLM may be arranged in the first direction. In some embodiments of the inventive concept, odd-numbered vertical active patterns of the vertical active patterns **140** in the respective column groups CLM may be offset in the second direction relative to even-numbered vertical active patterns of the vertical active patterns **140** in the respective column groups CLM. Accordingly, the vertical active patterns **140** in the respective column groups CLM may be arranged in a zigzag shape along the first direction.

According to the above-described manufacture method, after a plate stack structure **110** having the pads **108** are divided into a plurality of sub-plate stack structures **110s**, the vertical active patterns **140** passing through the respective sub-plate stack structures **110s** may be formed. Accordingly, stress that the sub-plate stack structures **110s** apply to the vertical active patterns **140** can be minimized.

The plate sacrificial patterns **107** may be formed of a material different from that of the plate insulation patterns **105**. Therefore, stress may occur due to the plate sacrificial patterns **107**. For example, when the plate sacrificial patterns **107** are formed of nitride, the plate sacrificial patterns **107** may generate stress in a direction parallel to a top surface of the substrate **100**. Particularly, due to the pads **108** of the stepped structure, a plate sacrificial pattern disposed at a relatively high level among the stacked plate sacrificial patterns **107** may generate more stress than a plate sacrificial pattern disposed at a relatively low level. The plate sacrificial pattern disposed at a relatively high level is referred to as a high-level plate sacrificial pattern, and the plate sacrificial pattern disposed at a relatively lower level is referred to as a low-level plate sacrificial pattern. This may be because a contact area between the high-level plate sacrificial pattern and a plate insulation pattern **105** adjacent thereto is smaller than a contacting area between the low-level plate sacrificial pattern and a plate insulation pattern **105** adjacent thereto. The plate insulation pattern **105** may moderate the stress of the plate sacrificial pattern **107**. Accordingly, the high-level plate sac-

ificial pattern having a small contacting area may provide more stress than the low-level plate sacrificial pattern having a large contacting area. If the vertical active patterns **140** are formed in the plate stack structure having the pads **108**, at least one portion of the vertical active patterns **140** may be inclined due to the stress of the high-level plate sacrificial pattern.

However, according to an embodiment of the inventive concept, as described above, after the plate stack structure **110** having the pads **108** is divided into the sub-plate stack structures **110s**, the vertical active pattern **140** may be formed in each of the sub-plate stack structures **110s**. Therefore, by reducing the stress, pattern failures of the vertical active patterns **140** can be reduced. As a result, a highly reliable and/or highly integrated 3D semiconductor memory device can be realized.

Referring to FIGS. **5A** to **5C**, at least one second trench **145**, which divides each of the sub-plate stack structure **110s** having the vertical active patterns **140** into a plurality of mold-stack structures **110m**, may be formed. According to FIGS. **5A** and **5C**, a second mask pattern **143** having at least one second opening may be formed on the substrate **100** having the vertical active patterns **140**. The second opening may define the location of the second trench **145**. The second mask pattern **143** covers the vertical active patterns **140**. Also, the second mask pattern **143** may cover the first isolation pattern **171**. The capping insulation patterns **115a** and the sub-plate stack structure **110s** may be sequentially etched using the second mask pattern **143** as an etch mask, and thus the second trench **145** may be formed. The mold-stack structures **110m** may be formed by formation of the second trench **145**. Moreover, a mold capping dielectric pattern **115b** may be formed on each of the mold-structures **110m**. The mold capping dielectric pattern **115b** corresponds to a portion of the capping dielectric pattern **115a**.

The mold-stack structures **110m** may include a plurality of mold insulation patterns **105m** and a plurality of mold sacrificial patterns **107m** that are stacked alternately and repeatedly. According to FIGS. **5A** and **5C**, the mold sacrificial patterns **107m** have mold-pads **108m** providing a stepped structure. The mold-pads **108m** may correspond to edges of the mold sacrificial patterns **107m** being stacked, respectively. In a plan view, as disclosed in FIG. **5A**, the second trench **145** may extend in parallel to the first trench **120** and cross the sub-pads **108s**. Therefore, the mold-pads **108m** of the stepped structure may be divided from the sub-pads **108s** of the stepped structure. The mold-pads **108m** are covered by the mold capping dielectric pattern **115b**.

The first trench **120** has a first width **W1** in the second direction, and the second trench **145** has a second width **W2** in the second direction. In some embodiments of the inventive concept, the first width **W1** of the first trench **120** may differ from the second width **W2** of the second trench **145**. The first width **W1** of the first trench **120** may be greater than the second width **W2** of the second trench **145**. However, the inventive concept is not limited thereto. The first width **W1** of the first trench **120** may be less than the second width **W2** of the second trench **145**. In some embodiments according to the inventive concept, the first width **W1** of the first trench **120** may be the substantially same as the second width **W2** of the second trench **145**.

The vertical active patterns **140** in each of the column groups CLM may pass through each of the mold-stack structures **110m**. In other words, the second trench **145** may be formed between a pair of adjacent column groups CLM in the

each sub-plate stack structure **110s**. After formation of the second trench **145**, the second mask pattern **143** may be removed.

Referring to FIGS. **6A** to **6C**, a second doped-region **150** may be formed in a well region **103** under the second trench **145**. The doped-region **150** may be doped with the second conductive dopant. The second doped-region **150** may correspond to a common source region. the second doped-region **150** may be formed after removing the second mask pattern **143**. In some embodiments according to the inventive concept, the second doped-region **150** may be formed after the second trench **145** is formed and before the second mask pattern **143** is removed.

A plurality of gap regions **155** may be formed by removing the mold sacrificial patterns **107m** of the mold-stack structure **110m**. A mold-stack structure **110m'** having the gap regions **155** may be supported by the vertical active patterns **140**. In some embodiments according to the inventive concept, after forming the gap regions **155**, the first isolation pattern **171** may remain.

Referring to FIGS. **7A** to **7C**, a plurality of gate patterns **165** may be formed in the gap regions **155**, respectively. A multi-layered dielectric layer **160** may be formed between a sidewall of the respective gate patterns **165** and a sidewall of the respective vertical active patterns **140**. For example, the multi-layered dielectric layer **160** may be conformally formed on a substrate **100** having the gap regions **155**, before formation of the gate patterns **165**. The multi-layered dielectric layer **160** may be conformally formed on inner surfaces of the gap regions **155**. A gate conductive layer filling the gap regions **155** may be formed on a substrate **100** having the multi-layered dielectric layer **160**. Subsequently, the gate patterns **165** respectively disposed in the gap regions **155** may be formed by removing the gate conductive layer outside the gap regions **155**. Thus, the multi-layered dielectric layer **160** may cover a bottom surface and top surface of the respective gate patterns **165**.

The multi-layered dielectric layer **160** may include a tunnel dielectric layer, a charge storage layer, and a blocking dielectric layer. The tunnel dielectric layer may be adjacent to the sidewall of the vertical active pattern **140**, and the blocking dielectric layer may be adjacent to the gate pattern **165**. The charge storage layer may be disposed between the tunnel dielectric layer and the blocking dielectric layer. The tunnel dielectric layer may include oxide and/or oxynitride. The charge storage layer may include a trap dielectric material having traps for storing an electric charge. For example, the charge storage layer may include nitride. The blocking dielectric layer may include a high dielectric material (for example, metal oxide such as hafnium oxide and/or aluminum oxide, etc) that has a dielectric constant higher than that of the tunnel dielectric layer. Furthermore, the blocking dielectric layer may further include a barrier dielectric material (for example, oxide) having an energy band gap that is greater than that of the high dielectric material.

The mold insulation patterns **105m** and the gate patterns **165** that are alternately and repeatedly stacked may provide the gate stack structure **110g**. Due to the mold-pads **108m** of the mold sacrificial patterns **107m**, the gate patterns **165** of the gate stack structure **110g** may include conductive pads **108g** constituting a stepped structure, respectively.

An uppermost gate pattern in the gate stack structure **110g** may correspond to a string selection gate, and a lowermost gate pattern in the gate stack structure **110g** may correspond to a ground selection gate. Also, the gate patterns **165** in the gate stack structure **110g** may include a plurality of cell gates.

The cell gates may be disposed between the ground selection gate and the string selection gate. The gate patterns **165** are formed of a conductive material. For example, the gate patterns **165** may include at least one of a doped semiconductor (for example, doped silicon, etc.), metal (for example, tungsten (W), aluminum (Al), copper (Cu), etc.), conductive metal nitride (for example, titanium nitride, tantalum nitride, tungsten nitride, etc.), and transition metal (for example, titanium (Ti), tantalum (Ta), etc.).

Referring to FIGS. **8A** to **8C**, after formation of the gate patterns **165**, a second isolation pattern **172** filling the second trench **145** may be formed. The second isolation pattern **172** may include oxide.

An interlayer dielectric **175** may be formed over the substrate **100**. A plurality of first contact plugs **180B**, which are respectively connected to the vertical active patterns **140** through the interlayer dielectric **175**, may be formed. A plurality of second contact plugs **180P**, which are respectively connected to the conductive pads **108g** through the mold capping dielectric pattern **115b**, may be formed. According to an embodiment of the inventive concept, the first contact plugs **180B** and the second contact plugs **180P** may be formed at the same time. In some embodiments according to the inventive concept, the first contact plugs **180B** and the second contact plugs **180P** may be sequentially formed irrespective of order.

A plurality of bit lines **190B** may be formed on the interlayer dielectric **175**. The bit line **190B** may be connected to the first contact plug **180B**. According to FIG. **8A**, the bit lines **190B** may be extended side by side in the second direction. The respective bit lines **190B** may be electrically connected to the vertical active patterns **140** that are arranged in the second direction to form one row. The vertical active patterns **140** in the respective column groups CLM may be connected to different bit lines **190B**, respectively.

A plurality of local interconnections **190L** may be formed on the interlayer dielectric **175**. The local interconnections **190L** may be connected to the second contact plug **180P**. According to FIG. **8A**, the local interconnections **190L** may extend in parallel with the bit lines **190B**. The respective local interconnections **190L** may be electrically connected to the conductive pads **108g** that are disposed at the same level and are included in a plurality of the gate stack structures **110g**. In this case, pads of gate patterns used as a string selection gate are not connected to the local interconnection **190L**. Gate patterns used as a string selection gate may be controlled independently from each other. In some embodiments according to the inventive concept, a landing pad **190K** may be formed on a second contact plug **180P** that is connected to a gate pattern used as the string selection gate.

According to an embodiment of the inventive concept, the bit lines **190B**, the local interconnections **190L** and the landing pads **190K** may be formed at the same time. In some embodiments according to the inventive concept, the bit lines **190B** may be formed after the local interconnections **190L** are formed or before the local interconnections **190L** are formed. According to an embodiment of the inventive concept, the bit lines **190B** and the local interconnections **190L** may be formed at the same level. In some embodiments according to the inventive concept, the bit lines **190B** and the local interconnections **190L** may be formed at different levels.

According to the above-described 3D semiconductor memory device, a plate stack structure **110** having the pads **108** may be divided into a plurality of sub-plate stack struc-

tures **110s**, and thereafter the vertical active patterns **140** may be formed. Therefore, modification of the vertical active patterns **140** can be minimized.

(Second Embodiment)

The same elements as those of the above-described first embodiment of the inventive concept use like reference numerals. To avoid repetitive description, moreover, the same processes as those of the above-described first embodiment of the inventive concept will not be described below.

FIGS. **9A** to **13A** are a plan views illustrating a method of manufacturing a 3D semiconductor memory device according to another embodiment of the inventive concept. FIGS. **9B** to **13B** are sectional views taken along line of FIGS. **9A** to **13A**, respectively. FIGS. **9C** to **13C** are sectional views taken along line IV-IV' of FIGS. **9A** to **13A**, respectively.

Referring to FIGS. **9A** to **9C**, a plate stack structure **110** may be formed on a substrate **100** having a well region **103**. A plurality of plate insulation patterns **105** and plate sacrificial patterns **107** in the plate stack structure **110** may have self-aligned sidewalls, respectively.

A plurality of vertical active patterns **140** may be formed through the plate stack structure **110**. Herein, the plate stack structure **110** having the vertical active patterns **140** may not have pads of a stepped structure. For example, an area of a lowermost plate sacrificial pattern in the plate stack structure **110** having the vertical active patterns **140** may be the substantially same as that of an uppermost plate sacrificial pattern in the plate stack structure **110** having the vertical active patterns **140** when viewed from a plan view.

According to FIG. **9A**, the vertical active patterns **140** passing through the plate stack structure **110** may be divided into a plurality of column groups CLM. The vertical active patterns **140** may contact the well region **103**.

Referring to FIGS. **10A** to **10C**, a first trench **120** may be formed to divide the plate stack structure **110** having the vertical active patterns **140** into a plurality of sub-plate stack structures **110s**. For example, a first mask pattern **118** having a first opening may be formed on the substrate **100** having the plate stack structure **110**. The first mask pattern **118** may cover the vertical active patterns **140**. The plate insulation patterns **105** and the plate sacrificial patterns **107** in the plate stack structure **110** may be sequentially etched using the first mask pattern **118** as an etch mask, and thus the first trench **120** may be formed. According to FIG. **10A**, each of the sub-plate stack structures **110s** may include a plurality of the column groups CLM. Each of the sub-plate stack structures **110s** may include a plurality of sub-plate insulation patterns **105s** and a plurality of sub-plate sacrificial patterns **107s** that are stacked alternately and repeatedly.

A first doped-region **125** may be formed in a well region **103** under the first trench **120**. The first doped-region **125** may be doped with a dopant having the same type as that of the well region **103**, or doped with a dopant having a type different from that of the well region **103**. In some embodiments according to the inventive concept, the first doped-region **125** may not be provided. After formation of the first trench **120**, the first mask pattern **118** may be removed. The first mask pattern **118** may be removed after or before the first doped-region **125** is formed.

Referring to FIGS. **11A** to **11C**, pads **108s'** constituting a stepped structure may be formed by patterning an edge of the each sub-plate stack structure **110s** having the vertical active patterns **140**. The pads **108s'** may correspond to edges of the sub-plate sacrificial patterns **107s** in the sub-plate structure **110s**. The pads **108s'** of the stepped structure may be formed by performing a patterning process, which includes a plurality of etch processes and a consumptive mask pattern

11

described above in the first embodiment of the inventive concept, for the sub-plate stack structure **110s**.

In some embodiments according to the inventive concept, after the plate stack structure **110** having the vertical active patterns **140** are divided into a plurality of sub-plate stack structures **110s**, the pads **108s'** constituting the stepped structure are formed at an edge of the sub-plate stack structure **110s**. That is, by dividing the plate stack structure **110** having the vertical active patterns **140** into a plurality of sub-plate stack patterns **110s**, stresses of the sub-plate sacrificial patterns **107s** in each of the sub-plate stack structures **110s** are moderated. Subsequently, the pads **108s'** of the stepped structure are formed in the each sub-plate stack structure **110s** having the moderated stresses. Therefore, the sub-plate stack structure **110s** having the pads **108s'** can minimize stress applied to the vertical active patterns **140**. As a result, variation of the vertical active patterns **140** can be minimized.

Referring to FIGS. **11A** to **11C**, a capping dielectric layer **115'** may be formed on a substrate **100** having the pads **108s'** of the stepped structure. The capping dielectric layer **115'** covers the pads **108s'** of the stepped structure. Furthermore, the capping dielectric layer **115'** may fill the first trench **120**. A top surface of the capping dielectric layer **115'** may be planarized. The top surface of the capping dielectric layer **115'** may be higher than an uppermost surface of the sub-plate stack structure **110s**. Therefore, the capping dielectric layer **115'** may cover the uppermost surface of the sub-plate stack structure **110s**. In this case, the capping dielectric layer **115'** may also cover upper surfaces of the vertical active patterns **140**. The capping dielectric layer **115'** may be formed of the same material as that of the capping dielectric layer **115** in the first embodiment of the inventive concept.

Referring to FIGS. **12A** to **12C**, at least one second trench **145** may be formed to divide each of the sub-plate stack structure **110s** into a plurality of mold-stack structures **110m**. For example, a second mask pattern **143** having a second opening may be formed on the capping dielectric layer **115'**. The second opening may define the second trench **145**. The second mask pattern **143** covers the vertical active patterns **140**. Furthermore, the second mask pattern **143** may cover a portion of the capping dielectric layer **115'** filling the first trench **120**. The capping dielectric layer **115'** and the sub-plate stack structure **110s** may be sequentially etched using the second mask pattern **143** as an etch mask, such that the second trench **145** may be formed. Moreover, the capping dielectric pattern **115a'** may be formed.

The mold-stack structure **110m** may include a plurality of mold insulation patterns **105m** and mold sacrificial patterns **107m** that are stacked alternately and repeatedly. Also, the mold-stack structure **110m** may include mold-pads **108m** constituting a stepped structure. The mold-pads **108m** may correspond to edges of the mold sacrificial patterns **107m** in each of the mold-stack structures **110m**, respectively. The capping dielectric pattern **115a'** may cover the mold-pads **108m**. Moreover, the capping dielectric pattern **115a'** may fill the first trench **120**. A second doped-region **150** may be formed in a well region **103** under the second trench **145**. The second mask pattern **143** may be removed. The second mask pattern **143** may be removed after or before the second doped-region **150** is formed.

Referring to FIGS. **13A** to **13C**, a plurality of gap regions may be formed by removing the mold sacrificial patterns **107m**, and then a plurality of gate patterns **165** may be formed in the gap regions, respectively. A multi-layered dielectric layer **160** may be foamed between side walls of each gate pattern **165** and vertical active pattern **140**. According to an embodiment of the inventive concept, after formation of the

12

gap region, and then the multi-layered dielectric layer **160** and the gate pattern **165** may be sequentially formed in the gap region. The gate stack structure **110g** may include a plurality of mold insulation patterns **105m** and a plurality of gate patterns **165** that are stacked alternately and repeatedly. As described above in the first embodiment of the inventive concept, due to pads **108m** of the mold sacrificial patterns **107m**, the gate patterns **165** in the gate stack structure **110g** have conductive pads **108g** constituting a stepped structure.

An isolation pattern **172** filling the second trench **145** may be formed. Then, an interlayer dielectric **175** may be formed over the substrate **100**. A plurality of first contact plugs **180B** respectively connected to the vertical active patterns **140** may be formed. According to an embodiment of the inventive concept, the first contact plug **180B** may be connected to the vertical active pattern **140** through the interlayer dielectric layer **175** and the capping dielectric pattern **115a'**. A plurality of second contact plugs **180P** respectively connected to a plurality of conductive pads **108g** may be formed. The second contact plug **180P** may be connected to the conductive pad **108g** through the interlayer dielectric layer **175** and the capping dielectric pattern **115a'**. The bit lines **190B**, the local interconnections **190L** and the landing pads **190K** that have been described above in the first embodiment of the inventive concept may be formed on the interlayer dielectric layer **175**.

The 3D semiconductor memory device according to the above-described embodiments of the inventive concept may be implemented in various types of semiconductor packages. For example, the 3D semiconductor memory devices that are manufactured in the above-described methods according to the embodiments of the inventive concept may be packaged in types such as Package on Package (PoP), Ball Grid Arrays (BGAs), Chip Scale Packages (CSPs), Plastic Leaded Chip Carrier (PLCC), Plastic Dual In-Line Package (PDIP), Die In Waffle Pack (DIWP), Die In Wafer Form (DIWF), Chip On Board (COB), Ceramic Dual In-Line Package (CERDIP), Plastic Metric Quad Flat Pack (MQFP), Thin Quad Flat Pack (TQFP), Small Outline Package (SOP), Shrink Small Outline Package (SSOP), Thin Small Outline Package (TSOP), Thin Quad Flat Pack (TQFP), System In Package (SIP), Multi Chip Package (MCP), Wafer Level Stack Package (WLSF), Die In Wafer Form (DIWF), Die On Waffle Package (DOWP), Wafer-level Fabricated Package (WFP), and Wafer-Level Processed Stack Package (WSP).

A package on which the 3D semiconductor memory devices manufactured in the above-described methods according to the embodiments of the inventive concept may further include a controller and/or a logic device for controlling the 3D semiconductor memory device.

In some embodiments according to the inventive concept, the plate stack structure having the stair-type pads may be divided into the plurality of sub-plate stack structures, and thereafter the vertical active pattern may be formed. In some embodiments according to the inventive concept, the plate stack structure having the vertical active pattern may be divided into the sub-plate stack structures, and then the pads of the stepped structure may be formed in the sub-plate stack structure. Accordingly, stress applied to the vertical active pattern can be minimized.

The above-disclosed subject matter is to be considered illustrative and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the true spirit and scope of the inventive concept. Thus, to the maximum extent allowed by law, the scope of the inventive concept is to be determined by the broadest permissible interpretation of the

## 13

following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

What is claimed is:

1. A method of manufacturing a Three Dimensional (3D) semiconductor memory device, the method comprising:
  - forming a plate stack structure comprising a plurality of plate insulation patterns and plate sacrificial patterns which are stacked alternately and repeatedly on a substrate;
  - forming edges of the plate sacrificial patterns as pads included in a stepped structure;
  - forming at least one first trench which divides the plate stack structure comprising the pads into a plurality of sub-plate stack structures;
  - forming a plurality of vertical active patterns passing through each of the sub-plate stack structures; and
  - forming at least one second trench which divides each of the sub-plate stack structures to provide a plurality of mold-stack structures, the method further comprising:
    - forming a well region doped with a first conductive dopant, in the substrate;
    - forming a first doped-region in the well region under the at least one first trench; and
    - forming a second doped-region doped with a second conductive dopant, in the well region under the at least one second trench.
2. The method of claim 1, further comprising forming a capping dielectric layer which covers the pads, before the first trench is formed,
  - wherein:
    - the at least one first trench is formed by patterning the plate stack structure comprising the pads and the capping dielectric layer,
    - the sub-plate stack structure comprises sub-pads constituting a stepped structure which are divided from the pads of the plate sacrificial patterns, and
    - the at least one second trench is formed by patterning the sub-plate stack structure and a portion of the capping dielectric layer covering the sub-pads.
3. The method of claim 2, wherein:
  - the mold-stack structure comprises a plurality of mold insulation patterns and mold sacrificial patterns which are stacked alternately and repeatedly, and
  - the method further comprises:
    - removing the mold sacrificial patterns to form a plurality of gap regions;
    - forming a multi-layered dielectric layer on sidewalls of the plurality of gap regions; and
    - forming a plurality of gate patterns in the gap regions on the multi-layered dielectric layer.
4. The method of claim 3, further comprising:
  - forming a first isolation pattern filling the at least one first trench before the vertical active patterns are formed; and
  - forming a second isolation pattern filling the at least one second trench after the gate patterns are formed.

## 14

5. The method of claim 1, wherein:
  - the first and second trenches extend in a first direction,
  - the at least one first trench has a first width in a second direction perpendicular to the first direction,
  - the at least one second trench has a second width in the second direction, and
  - the first width differs from the second width.
6. The method of claim 1, wherein:
  - the vertical active patterns passing through each of the sub-plate stack structures are divided into a plurality of column groups, in a plan view,
  - the at least one second trench is formed between a pair of the column groups adjacent to each other, and
  - the vertical active patterns in each of the column groups pass through each of the mold-stack structures.
7. The method of claim 6, wherein:
  - the vertical active patterns in each of the column groups are arranged in a first direction, and
  - odd-numbered vertical active patterns are offset in a second direction, perpendicular to the first direction relative to even-numbered vertical active patterns.
8. The method of claim 1, wherein:
  - the first doped-region is doped with the first conductive dopant, and
  - a dopant concentration of the first doped-region is higher than a dopant concentration of the well region.
9. The method of claim 1, wherein the second doped-region is doped with the second conductive dopant.
10. A method of manufacturing a Three Dimensional (3D) semiconductor memory device, the method comprising:
  - forming a plate stack structure including a plurality of insulation patterns and sacrificial patterns which are stacked alternately and repeatedly on a substrate;
  - forming edges of the sacrificial patterns as pads included in a stepped structure;
  - forming at least one first trench which divides the plate stack structure comprising the pads into a plurality of sub-plate stack structures, the first trench having a first width;
  - forming a plurality of vertical active patterns passing through each of the sub-plate stack structures;
  - forming a plurality of second trenches which divides each of the sub-plate stack structures to provide a plurality of mold-stack structures, the second trenches having a second width smaller than the first width;
  - removing the sacrificial patterns of the mold-stack structures exposed by the second trenches to form a plurality of gap regions between the insulating patterns, the gap regions partially exposing the vertical active patterns; and
  - forming a plurality of gate patterns in the gap regions, wherein the at least one first trench is disposed between the second trenches adjacent to each other.

\* \* \* \* \*